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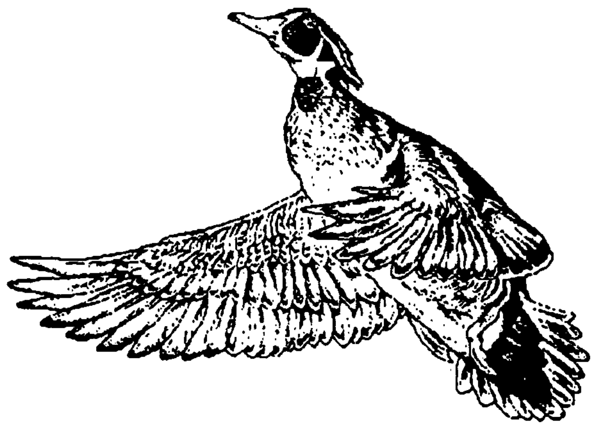

Wood Duck Investigations
W-118-R-1-2-3

Final Report to

Illinois Department of Natural Resources

Prepared by:

Aaron P. Yetter,
Stephen P. Havera,
and
Christopher S. Hine

Submitted by:

Stephen P. Havera
Illinois Natural History Survey, Havana

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EXECUTIVE SUMMARY

The abundance and use of natural tree cavities suitable for nesting by wood ducks (*Aix sponsa*) was studied at Sanganois Conservation Area (Sanganois CA) in central Illinois. Forty-one National Wetlands Inventory (NWI) habitat classes were observed on the study area; the dominant habitat type was palustrine forested wetland (2,159 ha). Ninety-seven 0.5-ha sample plots were located and searched from the ground for potentially suitable wood duck nesting cavities (potential cavities). A total of 326 potential cavities were located in 77 (79%) of the 97 sample plots. Two hundred sixty-four (81.0%) of the 326 potential cavities were located in trees stable enough to safely climb to determine whether the cavities were suitable for nesting by wood ducks (suitable cavities); 80 (30.3%) of the potential cavities were classified as suitable cavities.

The density of natural cavities suitable for nesting by wood ducks was 2.12 cavities/ha of palustrine forested wetland. Extrapolation provided an estimated density of 4,577 ($CI_{95} \pm 993$) suitable cavities in the 2,159 ha of palustrine forested wetland at Sanganois CA. Silver maple (*Acer saccharinum*) provided 74.3 percent of the density of suitable cavities followed by eastern cottonwood (*Populus deltoides*), willow (*Salix spp.*), red ash (*Fraxinus pennsylvanica*), and American sycamore (*Platanus occidentalis*). Silver maple also represented 59.8 percent of the basal area. However, based upon an importance value index, willow was the most important cavity-producing tree species followed by American sycamore and silver maple.

In 1994, wood ducks used pileated woodpecker (*Dryocopus pileatus*) cavities as nest sites in greater proportion than their availability, and wood ducks demonstrated a relatively high use of pileated woodpecker cavities in 1995. In both of the 1994 and 1995 nesting seasons, wood ducks utilized natural cavities with smaller entrance widths and lengths as well as those in

forest stands with larger basal areas. Additionally in 1994, wood ducks preferred suitable cavities with: 1) higher entrances; 2) smaller platform widths; 3) smaller bole diameters at the entrance; 4) larger basal areas of silver maple in the forest stand; 5) larger basal areas of trees in the immediate vicinity; and 6) higher densities of silver maple in the immediate vicinity. In 1995, wood ducks used suitable cavities with greater internal height above entrances and larger basal areas of American sycamore in their immediate vicinity.

Ten of 80 (12.5%) suitable cavities were used by wood ducks in 1994, and six of 46 (13.0%) suitable cavities were used by wood ducks in 1995. Wood duck nest densities in the 97 sample plots were 0.206 and 0.124 nests/ha of palustrine forested wetland in 1994 and 1995, respectively. Extrapolation provided an estimate of 445 ($CI_{95} \pm 268$) and 268 ($CI_{95} \pm 207$) wood duck nests in the 2,159 ha of palustrine forested wetlands during the springs of 1994 and 1995, respectively. The fate of one wood duck nest could not be determined in both the 1994 and 1995 nesting seasons; therefore, estimates of nest success were made from nine wood duck nests in 1994 and five wood duck nests in 1995. A simple estimate of nest success at Sanganois CA was 33.3 percent in 1994 and no hatched nests were found in 1995. The combined (1994 and 1995) estimate of wood duck nest success at Sanganois CA was 21.4 percent. Raccoons (Procyon lotor) were the primary predator of wood duck nests, and they destroyed six of the 14 nests whose fates were determined.

Protracted flooding in fall of 1992, the Great Flood of 1993, and spring of 1995 caused substantial tree mortality at Sanganois CA. Forty-three percent of the 75 trees with suitable cavities alive prior to January 1994 had perished by July 1995. Several other trees were showing signs of stress in July 1995 indicating that more trees may succumb.

The amount of time needed to climb and inspect a natural cavity using the single rope, rope-walking system was approximately 25 min. The height of the cavity entrance above the ground was significantly correlated with the amount of time needed to climb and inspect a natural cavity but it only accounted for 38 percent of the variation in the time required.

SUMMARY OF ACCOMPLISHMENTS

STUDY I THE IMPORTANCE OF NATURAL TREE CAVITIES FOR NESTING BY WOOD DUCKS IN ILLINOIS

JOB I-1 Abundance of Natural Tree Cavities in a Bottomland Forest

A ground survey of bottomland forest was completed in 1992 and 1993 to determine the number of natural cavities potentially suitable for nesting by wood ducks in quality floodplain habitat of the Sanganois Conservation Area at the confluence of the Illinois and Sangamon rivers in central Illinois. The tree species forming the largest density of suitable wood duck nest cavities per unit of basal area were willow, American sycamore, silver maple, eastern cottonwood, and red ash.

JOB I-2 Abundance of Natural Tree Cavities Suitable for Nesting by Wood Ducks and Nesting Success of Wood Ducks in Cavities

The natural cavities potentially suitable for nesting by wood ducks documented from the ground in JOB I-1 were climbed and inspected to determine the abundance of natural cavities actually suitable for use by nesting wood ducks. Suitable cavities were monitored for vertebrate use and wood duck nest success in 1994 and 1995. Natural cavity, cavity tree, and cavity site descriptive variables were measured to determine characteristics associated with cavities used by nesting wood ducks and those not used.

FINAL REPORT
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Federal Aid in Wildlife Restoration
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1 July 1992 through 30 June 1995

The results of Job I-2 are closely dependent upon the activities and results of the natural cavity investigation in Job I-1. For clarity and less redundancy, the final report presents both Job I-1 and Job I-2 combined rather than separately. The preceding summary of accomplishments addressed the activities for each job.

STUDY I THE IMPORTANCE OF NATURAL TREE CAVITIES FOR NESTING BY WOOD DUCKS IN ILLINOIS

OBJECTIVES:

To determine 1) an estimate of the abundance of natural tree cavities suitable for nesting by wood ducks and 2) the degree of utilization and success of wood ducks nesting in natural tree cavities in high quality bottomland habitat in the Illinois River valley.

JOB I-1 Abundance of Natural Tree Cavities in a Bottomland Forest

Objectives:

To determine the abundance of natural tree cavities in high quality wood duck habitat in the Illinois River valley.

To identify the species of trees most favorable to formation of natural cavities.

JOB I-2 Abundance of Natural Tree Cavities Suitable for Nesting by Wood Ducks and Nesting Success of Wood Ducks in Cavities

Objectives:

To determine the abundance of natural tree cavities suitable for nesting by wood ducks.

To determine the nesting success of wood ducks in natural tree cavities.

To determine the physical characteristics of tree cavities used for nesting by wood ducks.

INTRODUCTION

At the turn of the century, the wood duck (*Aix sponsa*) was considered by many to be on the brink of extinction and, as a result, wood ducks were granted full protection during the 1916-1940 waterfowl hunting seasons (Bellrose 1976). However, in recent years, wood ducks have been the most abundant nesting duck in Illinois (Havera 1992). Wood ducks currently rank second in the number of ducks harvested in Illinois and have been second in the harvest of ducks in the Mississippi Flyway for most of the last three decades (Havera 1992, Gamble 1994). The reestablishment of wood duck populations to current abundant levels rivals that of the white-tailed deer (*Odocoileus virginianus*), giant Canada goose (*Branta canadensis maxima*), and the wild turkey (*Meleagris gallopavo*) (Gigstead 1938, Bellrose 1976).

A primary limiting factor of wood duck populations, as well as other secondary cavity nesting (SCN) birds, has been the availability of suitable nesting cavities (von Haartman 1957; Bellrose et al. 1964; Haramis 1990, 1991; Coughlin and Higgins 1994; Newton 1994). However, other studies indicated that suitable cavities were not limiting SCN species (Boyer 1974, 1975; Robb 1986; Waters et al. 1990). Waters et al. (1990) suggested that before nest box programs are implemented to increase numbers of SCN birds, suitable cavity availability in forest stands should be determined.

Studies of artificial nest boxes have dominated the research on wood duck nesting habits (Hawkins and Bellrose 1940; Dreis and Hendrickson 1952; Carpenter 1953; Breckenridge 1956; Bellrose et al. 1964; Jones 1964; Bellrose and McGilvrey 1966; Shake 1967; Cunningham 1968; Strange 1970; Allen 1972; Teels 1975; Fiedler 1976; Doty 1984; Soulliere 1985; May 1986; Hepp et al. 1987; Semel et al. 1989, 1990; Dugger 1991; Semel and Sherman 1992; Richardson and Knapton 1993; Bellrose and Holm 1994; Borda 1994). Conversely, little research has been done exclusively on the use of natural tree cavities by nesting wood ducks (Gigstead 1938; Weier 1966; Prince 1968; Nagel 1969; Gilmer et al. 1978; Soulliere 1988; Lowney and Hill 1989; Lee 1991; Robb and Bookhout 1995; Sisson and Engstrom, In Press). Artificial nest boxes are considered ideal for management of local wood duck populations but may only contribute as little as 5 percent to the overall production of wood ducks in Illinois (Hawkins and Bellrose 1940, Bellrose and Holm 1994). Most of the wood duck production in Illinois and the Midwest comes from nests made in natural cavities (Bellrose and Holm 1994). Although wood duck populations in Illinois, the Mississippi Flyway, and Atlantic Flyway have increased, little is known about wood duck production and use of natural cavities, and no recent studies have investigated the importance of natural cavities for nesting wood ducks in Illinois.

A major problem in wood duck management has been the inability to estimate the size of their populations because of visibility constraints associated with the species inhabitation of densely forested areas and its secretive nature (Bellrose 1980, Fredrickson and Graber 1990). Estimation of wood duck population sizes and trends has been an important management goal in Illinois and the Mississippi Flyway because census techniques of this species have proven inadequate (Bellrose 1980, Fredrickson and Graber 1990, Anonymous 1993). Several techniques have been used to census wood duck populations with limited success including: stream float counts of pairs and broods, roost counts, hen call counts, aerial fixed-wing counts, ground counts, banding analyses, and monitoring artificial nest boxes.

Recently, states in the Atlantic and Mississippi flyways along with the U.S. Fish and Wildlife Service developed a wood duck management strategy to outline databases needed to effectively manage wood duck populations (Anonymous 1993). One specific objective of this strategy was to develop techniques providing estimates of regional breeding populations (Anonymous

1993). Therefore, to satisfy objectives of the Wood Duck Initiative undertaken by the U.S. Fish and Wildlife Service and the Atlantic and Mississippi flyway councils, knowledge of the regional wood duck breeding population was necessary to enhance management of this species endemic to North America. The present study of the abundance of natural cavities suitable for nesting by wood ducks, their use by nesting wood ducks, and nesting success was important in providing information toward estimating wood duck population size and growth in Illinois.

ACKNOWLEDGMENTS

Project W-118-R was supported by Federal Aid in Wildlife Restoration Act (Pittman-Robertson), with funds administered by the U.S. Fish and Wildlife Service and the Illinois Department of Natural Resources (IDNR), formerly the Illinois Department of Conservation. The following IDNR staff at the Sanganois Conservation Area provided assistance and advice during this project: D. Cowen, J. Hopps, R. Smith, and R. Mann. The following Illinois Natural History Survey (INHS) staff assisted with this project: M. Georgi provided assistance with computer software and photographic equipment as well as field assistance; L. Anderson, P. White, and K. Roat provided technical assistance; F. Bellrose, emeritus scientist, provided helpful comments and insight; L. Suloway delineated study area boundaries and quantified habitat types; and J. Brawn assisted with the study design and data analysis. H. Hobbs III, Professor of Biology, Wittenberg University, Springfield, Ohio, provided instruction of rope-climbing techniques.

STUDY AREA

The study area encompassed portions of southwestern Mason, northwestern Cass, and eastern Schuyler counties (Fig. 1) and included 3,835 ha (9,476 ac) of the state-owned Sanganois Conservation Area (Sanganois CA) (Fig. 2). Sanganois CA lies at the confluence of the Illinois and Sangamon rivers and is

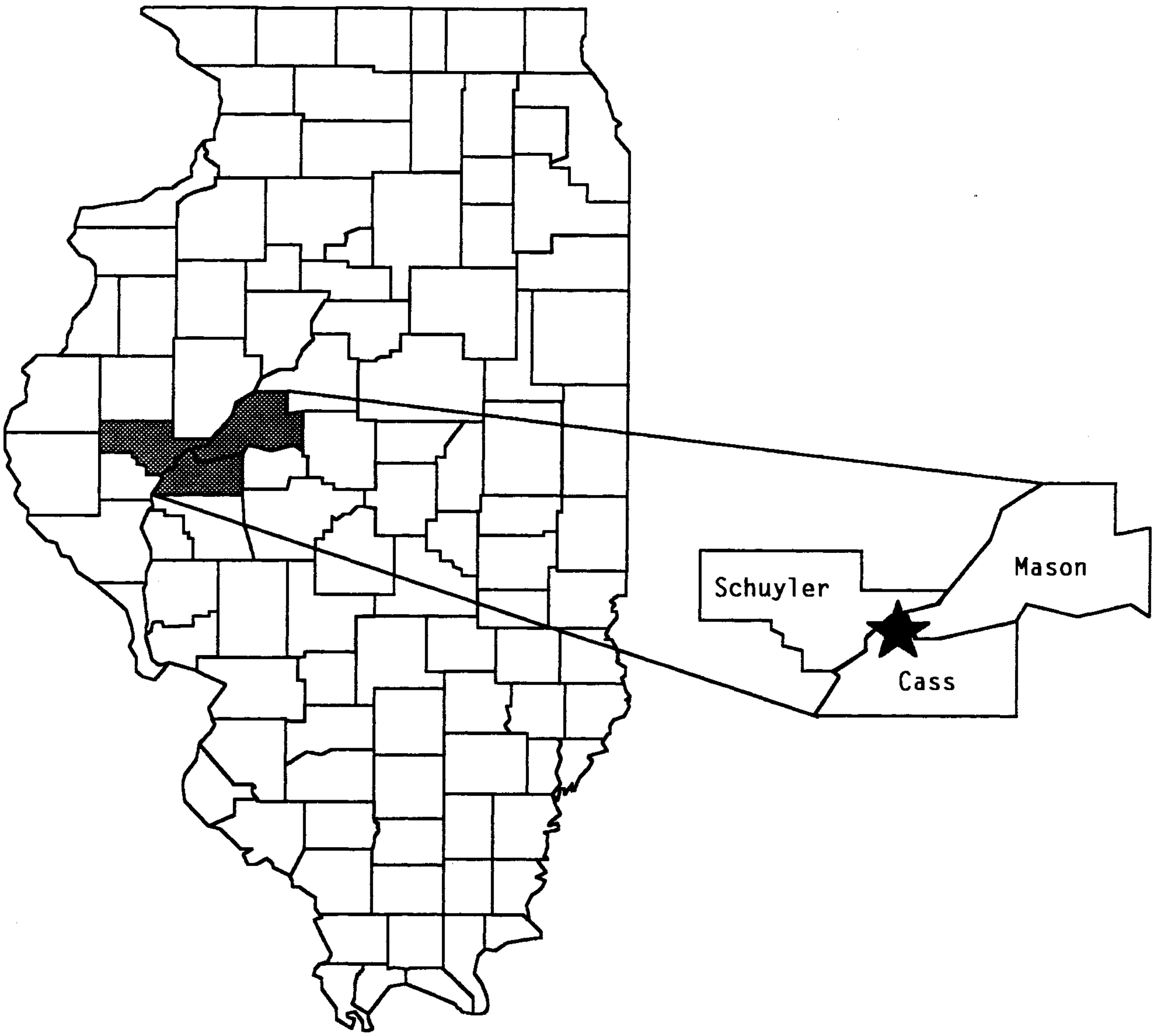

Figure 1. Wood duck study area in Mason, Cass, and Schulyer counties in west-central Illinois.

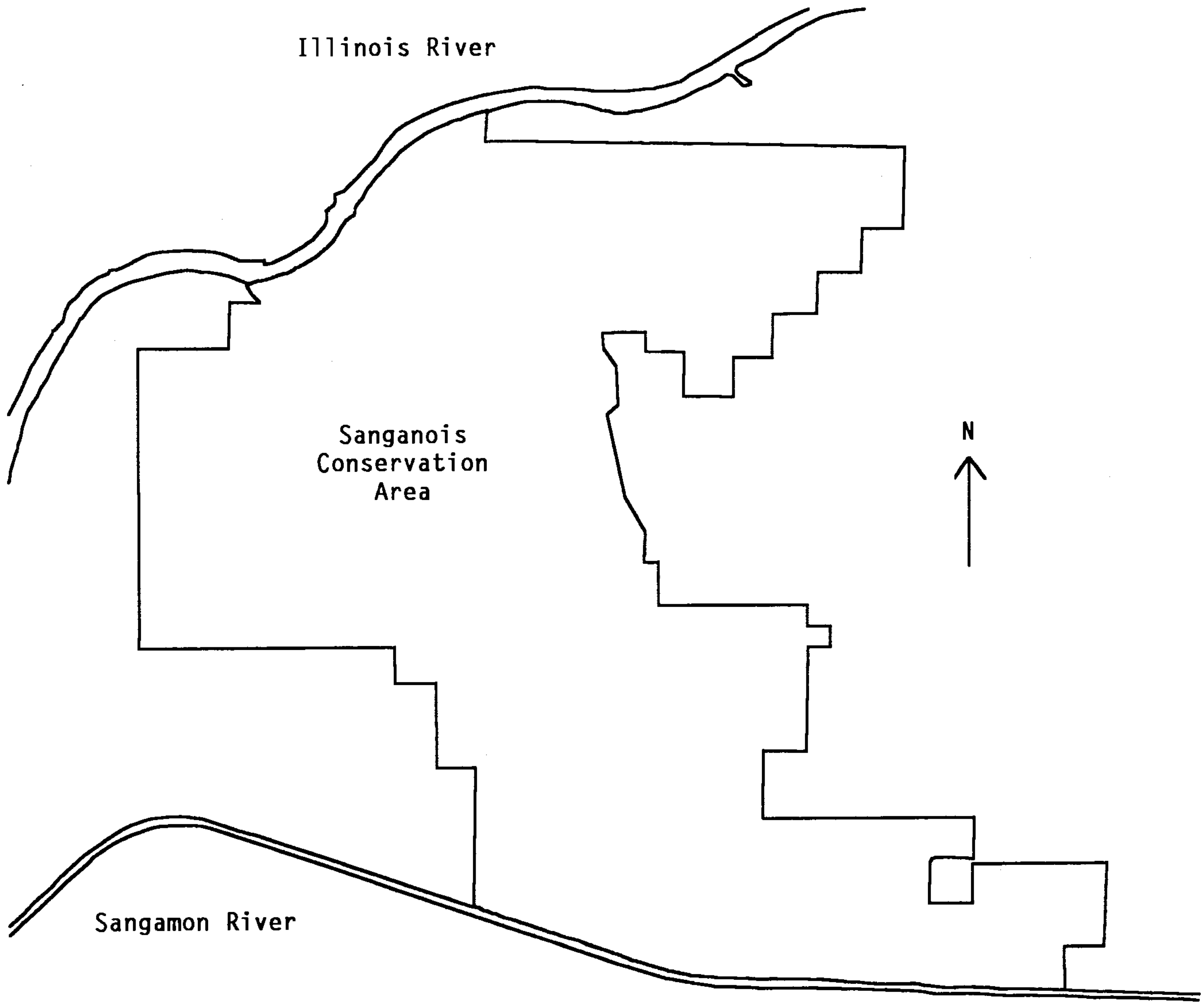

Figure 2. Natural cavity study area at the Sanganois Conservation Area.

a state-owned refuge and public hunting area. Sanganois CA was created in 1948 when the state of Illinois purchased several private duck clubs. The largest of these clubs was the Sanganois Gun Club from which the area received its name (Ill. Dep. Conserv. 1975). Over the years, other land purchases have expanded Sanganois CA to its current size of approximately 4,168 ha (10,300 ac).

Sanganois CA is a forested wetland in the floodplains of the Illinois and Sangamon rivers; habitats included are sloughs, bottomland lakes, ponds, and forest (Ill. Dep. Conserv. 1975). Major tree species on the area include: silver maple (*Acer saccharinum*), eastern cottonwood (*Populus deltoides*), willow (*Salix* spp), red ash (*Fraxinus pennsylvanica*), and American elm (*Ulmus americana*) (Ill. Dep. Conserv. 1975, Havera et al. 1980). Sanganois CA is considered to be one of the least disturbed bottomland areas along the Illinois River. The parcel known as Topper's Hole in the southwest corner of Sanganois CA was excluded from the study because of the lack of accessibility.

MATERIALS AND METHODS

Habitat Classification

Wetland and upland habitats on the study area were classified using National Wetlands Inventory (NWI) data stored on the Illinois Geographic Information System (IGIS) in Champaign, Illinois. NWI data were obtained from aerial photographs dated spring 1986. NWI data were ground-truthed for accuracy and identification of tree species within various habitat types.

Wood duck nesting habitat was defined as any palustrine forested wetland within the Sanganois CA regardless of water regime and/or special modifiers (Cowardin et al. 1979). Forested/scrub-shrub, forested/emergent, scrub-shrub, and scrub-shrub/emergent wetland habitats were excluded from sampling because the dominant trees growing in these habitats (determined from ground truthing) were willow saplings (Salix spp.) that were not large enough to produce cavities suitable for nesting wood ducks.

Surveys

A total of 109 sample points was selected for tree cavity investigations. Study area boundaries were drawn on NWI maps and placed on a digitizer. Latilong coordinates were randomly selected and located on a digitizing board using Measugraph 2.1 Software. Only those coordinates selected within desired habitats (palustrine forested wetland) were utilized. Two percent of the palustrine forested wetlands at Sanganois CA were surveyed for cavities suitable for nesting wood ducks. Sample points were located in bottomland timber with a Magellan NAV 1000 PRO Global Positioning System (GPS) and NWI maps. All-terrain vehicles (ATV) and a jon boat were used for transportation.

Circular plots (0.5 ha, 1.24 ac) (Bookhout 1986) centered on each sample point were marked using orange tree paint. All trees within the 0.5-ha plots were searched by more than one observer with binoculars. Trees containing potential nesting cavities were marked with tree paint and a numbered aluminum tag. Tree and cavity variables enabling observers to relocate potential nesting cavities for subsequent inspection were recorded including: tree species, tree dbh, tree status (dead or alive), tree height, tree location within the plot, entrance orientation, and entrance height.

Ground surveys were conducted at Sanganois CA for potentially suitable wood duck nest cavities (potential cavities) during the winters of 1992 and 1993 in spite of inclement weather and excessive flooding from the Great Flood of 1993. Following the survey, all trees having potential nesting cavities were ascended in winter and spring 1993-1994 to determine if the cavities were actually suitable for nesting by wood ducks (suitable cavities). All suitable cavities were inspected after the nesting season in July of 1994 and again in

June and July of 1995 to determine their use by wood ducks and other vertebrates (Gigstead 1938, Bookhout 1986, Bellrose and Holm 1994).

Natural cavities were examined for suitability using a modified version of the single rope, rope-walking system (Montgomery 1982, Meredith and Martinez 1986, Nadkarni 1988, Warild 1990, Padgett and Smith 1992, Stanback and Koenig 1994) and with climbing spikes, a safety belt, and lanyard (Robb 1986). Various methods of placing a climbing rope over a support branch in the cavity tree were employed. The best method was utilizing a compound bow equipped for bow fishing (Weier 1966, Greenlaw and Swinebroad 1967). After shooting a fish arrow over a support branch above the cavity, a heavy nylon string was tied to the fishing line (Munn 1991). The fishing arrow was retrieved thereby pulling the heavier nylon string over the branch. The nylon string was then tied to a climbing rope that was pulled over the branch and anchored.

Natural cavities were considered suitable as wood duck nest sites if they had entrance dimensions at least 6.5 x 9.0 cm (2.5 X 3.5 in) (Grice and Rogers 1965), platform dimensions at least 12.5 x 17.5 cm (5 X 7 in), and were not more than 500 cm (197 in) in depth (Bellrose et al. 1964, Bookhout 1986). Cavities were classified as unsuitable if they held water, contained excessive debris, were not deep enough to conceal the incubating hen (Robb 1986), or were hollow to the ground (F.C. Bellrose, Ill. Nat. Hist. Surv., pers. commun.).

Variables for the cavity, cavity tree, and forest surrounding the cavity were recorded at each suitable cavity (Table 1). Cavity entrance and internal dimensions were determined with a measuring tape. Tree height was determined with a clinometer. Diameter of the tree bole at the cavity entrance and dbh of the cavity tree were measured with a forester's dbh tape. The height of cavity entrances was determined with a measuring tape and was rounded to the

Table 1. Variables used to determine the suitability of natural tree cavities for nesting by wood ducks and descriptive variables for suitable natural cavities, their cavity trees, and the cavity sites at the Sanganois Conservation Area, 1992-1995.

Variable	Variable description
	Cavities
ORIENT	Cardinal direction of entrance orientation
EHEIGHT	Height of entrance above ground
EWIDTH	Horizontal width of lowest suitable cavity entrance
ELENGTH	Vertical length of lowest suitable cavity entrance
DEPTH	Distance from bottom of lowest suitable cavity entrance to the platform
HAE	Distance from top of lowest suitable cavity entrance to top of cavity
CWE	Horizontal width at lowest entrance height
CLE	Horizontal depth at lowest entrance height
PLATW	Horizontal width of the platform
PLATL	Horizontal depth of the platform
USE	Evidence of use by a vertebrate
FORM	Origin (natural, woodpecker, or both)
LOCATE	Location on tree (stem or branch)
TYPE	Type (normal, bucket, or combination)

Table 1. Continued.

Variable	Variable description
	Cavity trees
EDBH	Diameter of bole at entrance
SPECIES	Species or genus
STATUS	Status (alive or dead)
TDBH	Diameter of tree at breast height
THEIGHT	Total height
PLOT	Location in 0.5 ha circular plot
	Cavity sites
PTOTAL	Forest stand basal area
TTOTAL	Tree basal area in the immediate vicinity
DTOTAL	Tree density in the immediate vicinity

nearest 15 cm (0.5 ft). An instrument for cavity inspection was constructed from two 15.2 cm (6 in) sections of 5.1 cm (2 in) PVC pipe and a right angle PVC coupler. A mirror was attached inside the right angle coupler, and a small flashlight was attached to one end of the device. With this instrument, researchers could inspect the interiors of cavities for internal dimensions and evidence of use. Cavities, whose platforms were not visible or difficult to inspect for evidence of nesting activity, were examined by lowering adhesive tape on a string weighted with a lead fishing sinker (Nagel 1969, Bookhout 1986, Robb 1986). Thus, any nesting contents from the platform would adhere to the tape and could be examined; however, due to the limited effectiveness of this method, nest densities should be considered minimum estimates. Nests were considered successful if they hatched at least one egg, and nest success was determined from eggshells and membranes (Stewart 1957, Bellrose and Holm 1994). Vertebrate use of suitable cavities was determined by the presence of hair, feathers, or scats. Mammalian use indicated that evidence was observed in the cavity.

Forest Characteristics

Forest characteristics were examined to compare tree basal area and density at suitable cavity sites used by wood ducks with those not used by wood ducks. At each suitable cavity tree, a prism was used to determine the basal area of the forest stand. Stand basal area was determined by averaging measurements taken with a prism in each of four cardinal directions and 20 m (66 ft) from the cavity tree. Immediate vicinity basal area and tree density were determined within 0.05-ha (0.12-ac) circular plots centered around suitable cavity trees. Basal area in the immediate vicinity of the suitable cavities was measured using a dbh tape. All trees $\geq$ 10.0 cm (3.9 in) dbh within plots were included in immediate vicinity calculations excluding the cavity tree itself (Robb 1986). An importance rating was used to determine the most important suitable cavity-producing species. The importance rating was calculated by dividing the mean suitable cavity density by the mean basal area of that species (Robb 1986).

The age of suitable cavity trees was determined using an annual growth rate index. The age of a given tree was calculated by dividing its dbh by the annual growth rate for that species and dbh size class (Graber and Graber 1976). The age of the forest stand at Sanganois CA was calculated using the age of the oldest tree within the 0.05-ha circular plots centered on trees with suitable cavities.

The Mayfield method was used to determine annual longevity of suitable cavities (Mayfield 1961, 1975). Cavity mortality (a suitable cavity becoming unsuitable for wood duck nesting) was assumed to be the midpoint between our cavity visits. Cavity exposure was defined as the number of days between our visits.

Data Analysis

All data were computerized using Lotus 1-2-3 software Release 4.0 for DOS. Data were analyzed using the Statistical Analysis System (SAS) (SAS Inst. Inc. 1988a, 1988b). Because the same suitable cavities were monitored in 1994 and again in 1995 and the same female wood duck could potentially nest in the same cavity in both years, the cavity use data from 1994 and 1995 were analyzed separately. Chi-square goodness-of-fit and Fisher's exact tests of the UNIVARIATE procedure of SAS were applied to analyze categorical cavity and cavity tree characteristics (Zar 1984, Hinkle et al. 1988, SAS Inst. Inc. 1988a). Cavity orientation data were analyzed with a chi-square goodness-of-fit test for circular data (Zar 1984). Nonparametric Mann-Whitney tests of the NPAR1WAY procedure of SAS and multivariate analysis of variance (MANOVA) under the GLM procedure of SAS were employed to analyze differences between suitable cavities occupied and not occupied by wood ducks (Zar 1984, SAS Inst.

Inc. 1988b). When significant differences were detected between used and unused cavities in the MANOVA, analysis of variance (ANOVA) was utilized to determine which variables differed. A Pearson product-moment correlation of the CORR procedure of SAS (SAS Inst. Inc. 1988a) was employed to compare cavity height with the amount of time needed to climb and inspect a cavity. All statistical tests were considered significant when $\underline{P} \leq 0.05$.

RESULTS

Habitat

A total of 41 NWI habitat classes (Cowardin et al. 1979) representing 3,835 ha (9,476 ac) was documented on the study area (Table 2). Palustrine forested wetland was the dominant habitat type representing 2,159 ha (5,334 ac). Other habitats included lacustrine -- 665 ha (1,643 ac), upland -- 470 ha (1,162 ac), palustrine scrub-shrub -- 270 ha (666 ac), palustrine emergent and aquatic bed -- 135 ha (335 ac), palustrine forested/scrub shrub and forested/emergent -- 100 ha (248 ac), palustrine unconsolidated bottom -- 35 ha (87 ac), and riverine -- 0.34 ha (0.84 ac). Most of the NWI habitat classified as upland was bottomland forest cleared for agriculture.

Cavity Density

Of 109 0.5-ha sample plots, 12 were located in habitats other than palustrine forested wetland and were disregarded. The remaining 97 sample plots (Fig. 3) contained 326 potential nesting cavities; 77 plots contained $\geq$ 1 potential cavity.

One hundred eighty-four (56.4%) of the 326 potential cavities did not satisfy suitable nesting criteria, 80 (24.5%) were classified as suitable wood duck nest sites, 54 (16.6%) were located in trees not stable enough to safely climb, and 8 (2.5%) were lost to branch or tree fall before inspection (Table 3). Additional cavities were found during aerial cavity inspections. These additional cavities were not observed from the ground or were newly created.

Table 2. Coverage of National Wetlands Inventory (NWI) habitat classifications[a] for the study area at Sanganois Conservation Area.

Habitat code	Hectares	Acres
Lacustrine, Limnetic, Unconsolidated Bottom	541.9	1,338.8
L1UBHh	540.1	1,334.4
L1UBHhx	1.8	4.4
Lacustrine, Littoral, Aquatic Bed	51.7	127.7
L2ABG	1.2	3.0
L2ABGh	50.5	124.7
Lacustrine, Littoral, Unconsolidated Shore	71.6	176.8
L2UBGh	71.1	175.6
L2UBGhx	0.5	1.2
Palustrine, Aquatic Bed	1.8	4.4
PABGH	1.8	4.4
Palustrine, Emergent	133.7	330.4
PEM/FO1Fh	4.6	11.3
PEM/SS1A	7.2	17.9
PEM/SS1Ah	0.9	2.2
PEM/SS1Fh	61.2	151.2
PEMAh	2.3	5.6
PEMC	0.1	0.1
PEMCh	13.4	33.0
PEMCx	1.6	4.1
PEMF	0.7	1.8
PEMFh	41.6	102.9
PEMFx	0.1	0.3
Palustrine, Forested	2,175.1	5,374.6
PFO/SS1Ch	5.2	12.9
PFO1/EMFh	11.2	27.7
PFO1A	482.2	1,191.5
PFO1Ah	290.7	718.3
PFO1C	78.9	195.0
PFO1Ch	777.4	1,920.9
PFO1Fh	529.5	1,308.3
Palustrine, Scrub-Schrub	353.8	873.7
PSS/FO1Fh	84.0	207.4
PSS/FO1Ah	2.4	5.8
PSS/FO1Fh	37.8	93.4
PSS1/EMFh	66.8	165.2
PSS1A	4.6	11.4
PSS1Ah	11.0	27.2
PSS1C	0.1	0.1
PSS1Ch	61.9	152.8
PSS1Fh	85.2	210.4

Table 2. Continued.

Habitat code	Hectares	Acres
Palustrine, Unconsolidated Bottom	35.5	87.5
PUBF	0.6	1.4
PUBFh	5.1	12.6
PUBG	0.3	0.8
PUBGh	29.2	72.1
PUBGx	0.3	0.6
Riverine, Lower Perennial, Unconsolidated Bottom	0.3	0.8
R2UBHx	0.3	0.8
Upland	470.1	1,161.5
Total area	3,834.5	9,476.2

a Defined by Cowardin et al. (1979); NWI data obtained from aerial photographs dated spring 1986.

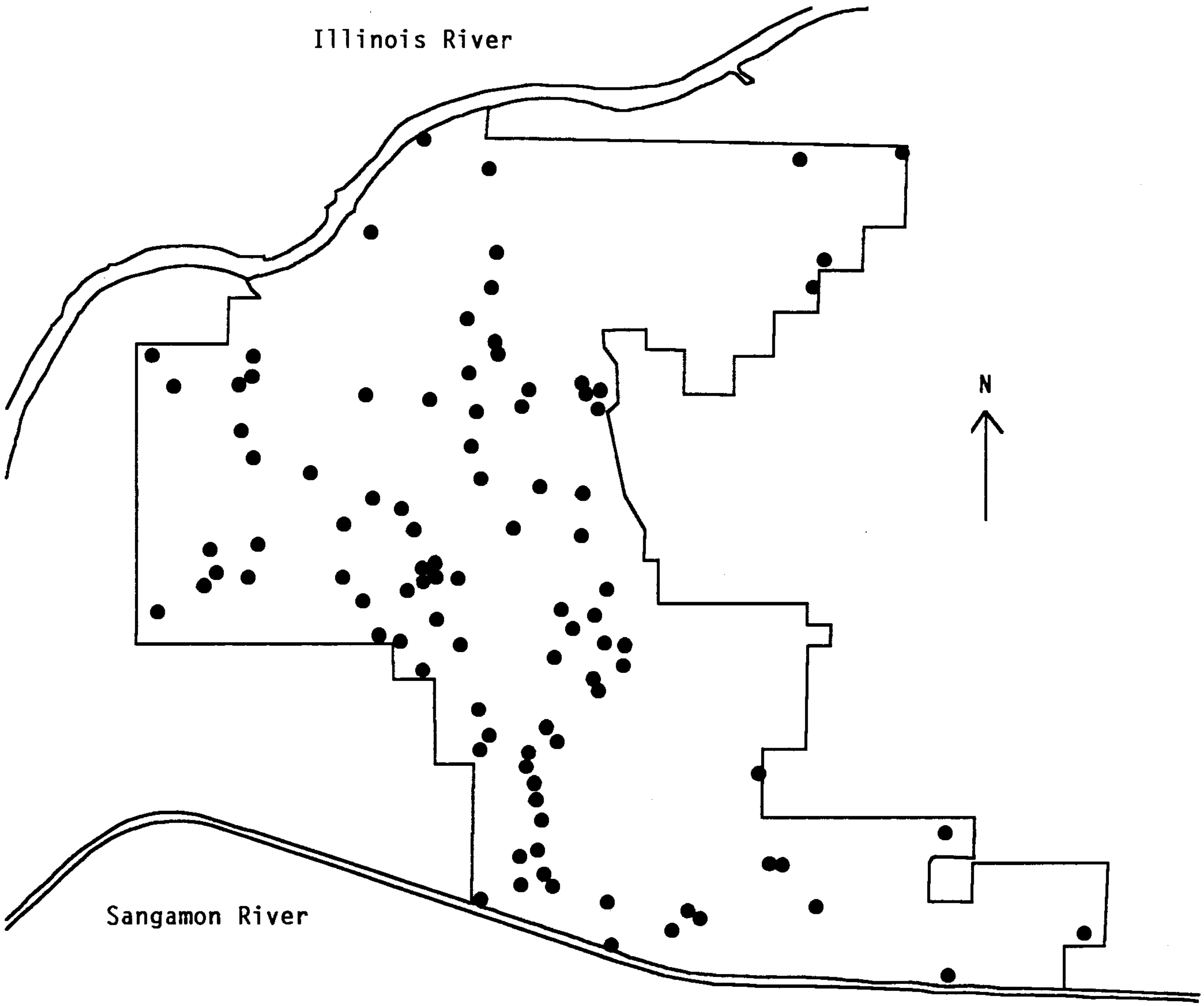

Figure 3. Distribution of sample plots for the investigation of natural cavities at the Sanganois Conservation Area.

Table 3. Suitability status of potential nest cavities for nesting by wood ducks at Sanganois Conservation Area, winter 1993-1994.

Cavity status	Number	Percent
Potential cavities		
Not suitable	184	56.4
Suitable	80	24.5
Not climable	54	16.6
Stem fall	8	2.5
Total	326	100.0
Additional cavities		
Not suitable	Not documented	
Suitable	6	
Not climable	2	

Six of the additional cavities were suitable, two were not climbable, and an undocumented number were unsuitable for nesting by wood ducks. Therefore, 86 suitable cavities were inspected and 56 potential cavities were considered not climbable in the 97 sample plots (Table 3).

In order to estimate the number of suitable cavities in the 56 potential cavities that were nonclimbable, we assumed that the ratio of suitable cavities to potential cavities was similar for the inspected and the noninspected cavities. Two hundred sixty four (81.0%) of the 326 potential cavities were inspected for suitability and 80 of the 264 (30.3%) were suitable wood duck nest sites. Therefore, 17 (30.3%) of the 56 nonclimable potential cavities were considered suitable as wood duck nest sites. Altogether, 103 (86 climbable and 17 nonclimbable) suitable cavities were found in the 97 sample plots at Sanganois CA, yielding a suitable cavity density of 2.12 cavities/ha (0.86 cavities/ac) (SE = 0.23, $CI_{95} \pm 0.46$). Therefore, extrapolation for the 2,159 ha (5,335 ac) of forested wetland capable of providing cavities at Sanganois CA yielded an estimate of 4,577 natural cavities ($CI_{95} \pm 993$) suitable for nesting by wood ducks.

The density of suitable cavities at Sanganois CA varied by tree species (Table 4). Silver maple accounted for 74.3 percent of the suitable cavity density. Other suitable cavity species were eastern cottonwood, willow, red ash, and American sycamore (Platanus occidentalis) representing 8.2, 8.0, 6.7, and 1.9 percent of the suitable cavity density, respectively. Likewise, silver maple represented 59.8 percent of the basal area at Sanganois CA (Table 4). Eastern cottonwood, red ash, and willow accounted for most of the remaining basal area representing 12.8, 11.9, and 2.9 percent, respectively. Silver maple was the dominant species, but it was not the most important cavity-producing species. Although willow ranked third and fourth with respect to cavity density and basal area, it was the most important cavity

Table 4. Mean density (cavities/ha) of suitable wood duck nest cavities, the mean basal area (m^2/ha), and the importance rating (cavities/m^2) of tree species at Sanganois Conservation Area, 1994.

	Suitable cavity density[a]		Basal area[b]		
Species	Mean	SD	Mean	SD	Importance rating
Silver maple	1.58	2.08	18.82	8.17	0.084
Eastern cottonwood	0.17	0.58	4.02	4.90	0.043
Willow	0.17	0.73	0.93	2.41	0.183
Red ash	0.14	0.64	3.75	4.10	0.038
American sycamore	0.04	0.29	0.43	1.18	0.095
Total	2.12	2.28	31.48	5.82	0.067

[a] Suitable cavity density was determined from 97 0.5-ha circular plots, spring 1994.

[b] Basal area was determined with a basal area prism near suitable cavity trees (n = 80), November 1994.

producer on the area with an importance rating of 0.183 cavities/m^2 followed by American sycamore (0.095 cavities/m^2) and silver maple (0.084 cavities/m^2) (Table 4).

Willow was also the youngest cavity-producing species at Sanganois CA (Table 5). The mean age of cavity-producing species was between 53 and 68 yrs with the exception of red ash, which had a mean age of 108 yrs (Table 5). The minimum age for red ash to produce a suitable cavity was 80.5 yrs. The mean age of the forest stand at Sanganois CA was 92.2 yrs.

Cavity Loss

Of the 86 suitable cavities detected, three were no longer safe for inspection by July 1995, leaving 83 for calculating suitable cavity loss rates. Nesting suitability of 13 (15.7%) of the 83 cavities deteriorated between August 1993 and July 1995. Five of the 13 cavities became unsuitable for wood duck use when their platforms disintegrated, 4 cavity trees fell, 2 cavities held water during the wet spring of 1995, 1 platform became exposed, and 1 cavity was filled with twigs presumably by nesting activity of house wrens (Troglodytes aedon). The daily "survival" of suitable cavities at Sanganois CA was 0.9997, which resulted in a 88.28 percent annual survivorship.

Cavity Use

Raccoons and Fox Squirrels.--In the fall/winter of 1993-1994, 48 of 81 (59.3%) suitable cavities had evidence of vertebrate use including wood ducks (Table 6). Animal use decreased to 30 of 81 (37.0%) suitable cavities by July 1994. Raccoons (Procyon lotor) and fox squirrels (Sciurus niger) were major users of cavities in fall and winter. However, fox squirrel use of cavities decreased to 2.5 percent during July 1994. No evidence of wood duck use was found during fall/winter, indicating decomposition and/or removal of wood duck nest materials.

Table 5. Mean age[a] (yrs) of trees with suitable wood duck nest cavities at Sanganois Conservation Area, November, 1994.

Species	Tree age Mean	SD	n
Red ash	107.7	21.9	6
American sycamore	68.2	22.5	2
Eastern cottonwood	68.0	4.6	4
Silver maple	54.9	18.6	61
Willow	52.7	22.7	7
Mean of all suitable cavity trees	59.5	23.4	80

[a] Tree age calculated according to Graber and Graber (1976).

Table 6. Number and percent of suitable wood duck nest cavities with indications of vertebrate use[a] at Sanganois Conservation Area during fall/winter 1993-1994, spring 1994, and spring 1995.

Species	Fall/winter 1993-1994		Spring[b] 1994		Spring[b] 1995	
	n	Percent	n	Percent	n	Percent
Raccoon	23	28.4	14	17.3	17	34.0
Fox squirrel	11	13.6	2	2.5	4	8.0
Opossum	1	1.2	0		0	
Yellow-shafted flicker	1	1.2	1	1.2	0	
House wren	0		1	1.2	0	
Wood duck	0		5	6.2	2	4.0
Wood duck and raccoon	1	1.2	5	6.2	1	2.0
Wood duck and woodpecker	0		0		1	2.0
Wood duck and bullsnake	0		0		1	2.0
Wood duck and flying squirrel	0		0		1	2.0
Raccoon or opossum	3	3.7	0		0	
Unknown bird	6	7.4	1	1.2	1	2.0
Raccoon and unknown bird	0		0		1	2.0
Unknown mammal	1	1.2	1	1.2	3	6.0
Unknown bird and fox squirrel	1	1.2	0		0	
Flooded and not used	0		0		20[c]	
Flooded and raccoon	0		0		4[d]	8.0
No evidence of use	33	40.7	51	63.0	14	28.0
Total	81		81[e]		50[d]	

[a] Use was determined by the presence of hairs, feathers, and/or scats.
[b] Inspected in July 1994 and June-July 1995.
[c] Not included in animal use calculations.
[d] Excluded from calculations of wood duck use of cavities. For wood duck use of cavities in spring 1995, n = 46.
[e] House wren nesting activity reduced the number of available suitable wood duck nesting cavities to 80.

During June-July 1995, 20 suitable cavities were flooded eliminating all signs of vertebrate use (Table 6); consequently, these cavities were not included in the use comparisons. An additional four cavities were flooded but had evidence of raccoon use after water levels receded. Fourteen of the 50 (28.0%) suitable cavities were not used in 1995; the remaining 36 (72.0%) had evidence of use. Raccoons used 23 of the 50 (46.0%) suitable cavities. Fox squirrel use of suitable cavities remained relatively low at 8 percent during July 1995.

Wood Ducks 1994.--Eighty cavities were considered suitable wood duck nest sites during spring 1994 (Table 6). Ten of 80 (12.5%) suitable cavities were used by nesting wood ducks, yielding a nest density of 0.206 nests/ha (0.083 nests/ac) (SE = 0.062, $CI_{95} \pm 0.124$). This nest density should be considered as a minimum estimate.

Eighty percent of the wood duck nest cavities were located in silver maple (Table 7). One nest was located in an eastern cottonwood and one was in an American sycamore. The nesting use by wood ducks of tree species containing suitable cavities was in proportion to their availability ($\underline{X}^2$ = 5.02, 4 df, $\underline{P}$ = 0.285).

Eighty percent of wood duck nests were located in normal (enclosed, side-entrance) cavities, and the remaining 20 percent were located in combination-type cavities (Table 7). Goodness-of-fit tests detected differences in the use by wood ducks of the three types of cavities ($\underline{X}^2$ = 11.21, 2 df, $\underline{P}$ = 0.004). However, when combination-type cavities were excluded, wood duck use of normal and bucket cavities was proportional to their availability (Fisher's exact test, $\underline{P}$ = 0.099). The type of stem (trunk or branch) containing suitable cavities was used in proportion to its availability (Fisher's exact test, $\underline{P}$ = 0.086).

Table 7. Numbers and percents for characteristics of suitable cavities used and not used by wood ducks for nesting at Sanganois Conservation Area during spring 1994. $\underline{P}$ values represent frequency distribution comparisons using Fisher's exact tests (2 x 2 comparison) or Chi-square goodness-of-fit tests.

	Suitable cavities				
	Used by wood ducks		Not used by wood ducks		
Variable	n	Percent	n	Percent	P
Tree species					
Silver maple	8	80.0	53	75.7	0.285
Red ash	0	0.0	6	8.6	
Willow	0	0.0	7	10.0	
Eastern cottonwood	1	10.0	3	4.3	
American sycamore	1	10.0	1	1.4	
Cavity type					
Normal	8	80.0	48	68.6	0.004
Bucket	0	0.0	21	30.0	0.099[a]
Combination	2	20.0	1	1.4	
Stem type					
Trunk	6	60.0	59	84.3	0.086
Branch	4	40.0	11	15.7	
Tree status					
Alive	6	60.0	57	81.4	0.207
Dead	4	40.0	13	18.6	
Cavity formation					
Natural	2	20.0	64	91.4	<0.001
Pileated woodpecker	6	60.0	6	8.6	<0.001[b]
Both	2	20.0	0		

[a] Fisher's exact test $\underline{P}$ value comparing normal side entrance vs. bucket cavities.
[b] Fisher's exact test $\underline{P}$ value comparing pileated woodpecker vs. naturally formed cavities.

Sixty percent of the wood duck nests were located in living trees (Table 7); however, suitable cavities in dead and living trees were used in proportion to their availability (Fisher's exact test, $P = 0.207$). Suitable cavities were classified as being formed by (1) natural factors, (2) pileated woodpeckers (*Dryocopus pileatus*), or (3) both. Goodness-of-fit tests indicated that wood ducks did not use these cavities in proportion to their availability ($X^2 = 34.84$, 2 df, $P < 0.001$) (Table 7). When cavities that were formed by both natural factors and pileated woodpeckers were excluded, suitable cavities excavated by pileated woodpeckers were used in greater proportion than their availability (Fisher's exact test, $P < 0.001$), indicating a preference by wood ducks for pileated woodpecker cavities (Table 7).

Goodness-of-fit tests for circular data verified that entrances of suitable cavities were not oriented in any specific direction ($X^2 = 7.14$, 7 df, $P \geq 0.05$), and the orientation of wood duck nest cavities did not differ from those of unused suitable cavities ($X^2 = 6.61$, 7 df, $P > 0.05$).

Variables representing suitable cavities and their respective trees differed between suitable cavities used and not used by nesting wood ducks (Table 8). The entrance height (EHEIGHT) of cavities used by wood ducks ($\bar{x}$ = 9.40 m, SD = 3.82) was significantly greater than unused suitable cavities ($\bar{x}$ 6.47 m, SD = 4.03) (Mann-Whitney $|z| = 2.23$, $P = 0.026$). Wood duck nest cavities had smaller horizontal entrance widths (EWIDTH) ($\bar{x}$ = 9.91 cm, SD = 5.51) (Mann-Whitney $|z| = 3.45$, $P = 0.001$), vertical entrance lengths (ELENGTH)($\bar{x}$ = 12.83 cm, SD = 3.56)(Mann-Whitney $|z| = 4.03$, $P < 0.001$), and platform widths (PLATW) ($\bar{x}$ = 18.63 cm, SD = 2.98) (Mann-Whitney $|z| = 2.47$, $P = 0.013$) than suitable cavities not used by wood ducks. Trees with suitable cavities used by wood ducks had smaller diameter boles at the cavity entrance (EDBH) ($\bar{x}$ = 41.12 cm, SD = 6.81) than those with unused cavities ($\bar{x}$ = 52.65

Table 8. Cavity and cavity tree variables for used and unused suitable wood duck nest cavities at Sanganois Conservation Area during spring 1994. Row means not sharing the same letter were statistically different ($\underline{P} \leq 0.05$, Mann-Whitney tests).

	Suitable cavities			
	Used by wood ducks		Not used by wood ducks	
Variables	Mean ($\underline{n}$)	SD	Mean ($\underline{n}$)	SD
Cavity[a]				
EHEIGHT[b]	9.40 (10) A	3.82	6.47 (70) B	4.03
EWIDTH[c]	9.91 (10) A	5.51	17.63 (70) B	8.99
ELENGTH[c]	12.83 (10) A	3.56	40.41 (70) B	29.62
DEPTH[c]	98.04 (10) A	72.09	73.79 (70) A	91.84
HAE[c,d]	48.82 (9) A	40.38	31.98 (66) A	45.57
CWE[c]	22.10 (10) A	5.87	28.58 (70) A	16.16
CLE[c]	20.96 (10) A	4.69	27.90 (70) A	14.41
PLATW[c,e]	18.63 (9) A	2.98	28.23 (66) B	13.33
PLATL[c,e]	21.03 (9) A	5.93	28.92 (66) A	13.99
Tree[a]				
EDBH[c]	41.12 (10) A	6.81	52.65 (70) B	17.91
THEIGHT[b]	22.25 (10) A	7.07	19.95 (70) A	6.84
TDBH[b]	68.20 (10) A	25.17	63.15 (70) A	19.83

[a] EHEIGHT = entrance height; EWIDTH = entrance width; ELENGTH = entrance length; DEPTH = cavity depth below entrance; HAE = height of cavity above entrance; CWE = cavity width at entrance; CLE = cavity length at entrance; PLATW = platform width; PLATL = platform length; EDBH = diameter of the tree bole at entrance; THEIGHT = tree height; TDBH = diameter of bole at breast height.

[b] In meters.

[c] In centimeters.

[d] HAE could not be measured for one wood duck nest cavity and four unused suitable cavities.

[e] Platform dimensions could not be measured for one wood duck nest cavity and four unused suitable cavities.

cm, SD = 17.91) (Mann-Whitney $|z|$ = 2.04, $\underline{P}$ = 0.042). No other differences were detected.

The basal area and density of trees near and also in the immediate vicinity of suitable cavities used and not used by wood ducks differed (Tables 9 and 10). The forest stand basal area of all trees (PTOTAL) surrounding wood duck nest cavities ($\underline{\bar{x}}$ = 34.72 m^2/ha, SD = 5.18) was greater than the PTOTAL around unused suitable cavities ($\underline{\bar{x}}$ = 31.02 m^2/ha, SD = 5.80) (Mann-Whitney $|z|$ = 1.96, $\underline{P}$ = 0.049) (Table 9). Wood duck nest cavity sites had higher values of forest stand basal area for silver maple ($\underline{\bar{x}}$ = 24.73 m^2/ha, SD = 8.77) than unused suitable cavities ($\underline{\bar{x}}$ = 17.98 m^2/ha, SD = 7.79) (Mann-Whitney $|z|$ = 2.18, $\underline{P}$ = 0.029). The basal area of trees in the immediate vicinity (TTOTAL) of wood duck nest sites was larger ($\underline{\bar{x}}$ = 52.92 m^2/ha, SD = 19.36) than at unused suitable cavities ($\underline{\bar{x}}$ = 37.94 m^2/ha, SD = 15.57) (Mann-Whitney $|z|$ = 2.10, $\underline{P}$ = 0.036), and the basal area of swamp privet (<u>Forestiera</u> <u>acuminata</u>) in the immediate vicinity of wood duck nest cavities ($\underline{\bar{x}}$ = 0.24 m^2/ha, SD = 0.51) was larger than that around unused suitable cavities ($\underline{\bar{x}}$ = 0.02 m^2/ha, SD = 0.14) (Mann-Whitney $|z|$ = 2.35, $\underline{P}$ = 0.019) (Table 10). The density of silver maple in the immediate vicinity of cavity trees was greater at wood duck nest sites ($\underline{\bar{x}}$ = 12.5 trees/0.05 ha, SD = 3.6) than near unused suitable cavity sites ($\underline{\bar{x}}$ = 8.57 trees/0.05 ha, SD = 6.23) (Mann-Whitney $|z|$ = 2.16, $\underline{P}$ = 0.030) (Table 10). Likewise, the density of swamp privet ($\underline{\bar{x}}$ = 1.10 trees/0.05 ha, SD = 2.33) was greater in the immediate vicinity of wood duck nest cavities than unused suitable cavities ($\underline{\bar{x}}$ = 0.09 trees/0.05 ha, SD = 0.61) (Mann-Whitney $|z|$ = 2.35, $\underline{P}$ = 0.019). However, the importance of swamp privet basal area and density should be viewed cautiously because swamp privet was found at only four sites, two of which were used by wood ducks for nesting.

Table 9. Forest stand basal area (m^2/ha) surrounding trees containing suitable cavities used and not used by nesting wood ducks at Sanganois Conservation Area, 1994. Row means not sharing the same letter were statistically different ($P \leq 0.05$, Mann-Whitney tests).

	Basal areas surrounding suitable cavities			
	Used by wood ducks (n=10)		Not used by wood ducks (n=70)	
Species	Mean	SD	Mean	SD
Silver maple	24.73 A	8.77	17.98 B	7.79
Eastern cottonwood	3.84 A	4.17	4.05 A	5.02
Red ash	3.84 A	3.42	3.73 A	4.21
Elm	0.75 A	1.62	1.51 A	1.86
American sycamore	0.69 A	2.18	0.39 A	0.97
Willow	0.40 A	0.72	1.00 A	2.55
River birch	0.29 A	0.62	0.21 A	0.69
Pecan	0.11 A	0.24	0.42 A	0.91
Unknown	0.06 A	0.18	0.25 A	0.45
Pin oak	0.00 A	0.00	0.71 A	3.04
White oak	0.00 A	0.00	0.18 A	0.58
Black oak	0.00 A	0.00	0.09 A	0.75
Box elder	0.00 A	0.00	0.35 A	0.88
Persimmon	0.00 A	0.00	0.01 A	0.07
Mulberry	0.00 A	0.00	0.03 A	0.17
Hackberry	0.00 A	0.00	0.07 A	0.27
Hickory	0.00 A	0.00	0.01 A	0.07
Sassafras	0.00 A	0.00	0.01 A	0.07
Honey locust	0.00 A	0.00	0.02 A	0.15
Total	34.72 A	5.18	31.02 B	5.80

Table 10. Basal area (m^2/ha), density (trees/0.05 ha), and dbh (cm) of trees within 0.05-ha circular plots (immediate vicinity) centered on trees with suitable cavities used and not used by wood ducks at Sanganois Conservation Area, 1994. Row means not sharing the same letter were statistically different ($\underline{P} \leq 0.05$, Mann-Whitney tests).

	Suitable cavities			
	Used by wood ducks (n=10)		Not used by wood ducks (n=70)	
Tree variables by species	Mean	SD	Mean	SD
Basal area (m^2/ha)				
Silver maple	38.84 A	26.33	23.95 A	17.80
Eastern cottonwood	5.84 A	9.57	3.45 A	6.76
Red ash	4.96 A	7.54	4.32 A	6.27
Elm	1.04 A	2.30	1.85 A	2.86
American sycamore	0.77 A	2.45	0.37 A	1.59
Unknown	0.62 A	1.81	0.16 A	0.73
Willow	0.56 A	1.78	1.41 A	5.12
Swamp privet	0.24 A	0.51	0.02 B	0.14
Pecan	0.04 A	0.13	0.45 A	1.72
Black oak	0.00 A	0.00	0.30 A	2.49
Pin oak	0.00 A	0.00	0.68 A	4.35
White oak	0.00 A	0.00	0.36 A	1.12
Box elder	0.00 A	0.00	0.21 A	0.92
Mulberry	0.00 A	0.00	0.06 A	0.32
River birch	0.00 A	0.00	0.22 A	1.31
Hackberry	0.00 A	0.00	0.13 A	1.13
Redbud	0.00 A	0.00	0.01 A	0.05
Total	52.92 A	19.36	37.94 B	15.57
Density (trees/0.05 ha)				
Silver maple	12.50 A	3.60	8.57 B	6.23
Red ash	3.00 A	4.88	2.49 A	3.90
Elm	2.00 A	5.66	3.43 A	4.63
Eastern cottonwood	1.20 A	2.30	0.66 A	1.35
Swamp privet	1.10 A	2.33	0.09 B	0.61
American sycamore	0.30 A	0.95	0.16 A	0.53
Unknown	0.30 A	0.67	0.20 A	0.69
Pecan	0.10 A	0.32	0.19 A	0.60
Willow	0.10 A	0.32	0.67 A	2.10
Black oak	0.00 A	0.00	0.04 A	0.36
Pin oak	0.00 A	0.00	0.23 A	1.16
White oak	0.00 A	0.00	0.16 A	0.44
Box elder	0.00 A	0.00	0.26 A	0.93
Mulberry	0.00 A	0.00	0.07 A	0.31
River birch	0.00 A	0.00	0.10 A	0.42
Hackberry	0.00 A	0.00	0.14 A	1.20
Redbud	0.00 A	0.00	0.03 A	0.24
Total	20.60 A	7.07	17.47 B	7.71
dbh (cm) Total	38.65 A	14.33	34.20 A	9.76

The hypothesis that the overall wood duck use of cavities did not differ across the cavity, cavity tree, and cavity site variables was examined for EHEIGHT, EWIDTH, ELENGTH, DEPTH, HAE, CWE, CLE, PLATW, PLATL, EDBH, TDBH, THEIGHT, PTOTAL, TTOTAL, and DTOTAL (Table 1). Seventy-one observations were used in the analysis and nine observations were excluded because of missing values. The MANOVA model detected significant differences between cavities used by wood ducks and unused suitable cavities (Hotelling-Lawley Trace, $\underline{F}$ = 2.56, 15, 55 df, $\underline{P}$ = 0.006). ANOVA indicated EWIDTH ($\underline{F}$ = 5.15, 70 df, $\underline{P}$ = 0.026) and ELENGTH ($\underline{F}$ = 6.93, 70 df, $\underline{P}$ = 0.011) were significantly smaller for wood duck nest cavities than for unused suitable cavities. PTOTAL ($\underline{F}$ = 4.76, 70 df, $\underline{P}$ = 0.033) and TTOTAL ($\underline{F}$ = 5.25, 70 df, $\underline{P}$ = 0.025) were larger for wood duck nest cavities than for unused suitable cavities. However, $\underline{R}^2$ values for all four variables (EWIDTH, ELENGTH, PTOTAL, TTOTAL) were low (0.065-0.091) and explained little of the variation in the wood duck use of suitable cavities.

Wood Ducks 1995.--Due to the record high floods on the Illinois River at Beardstown, Illinois, (8 km downstream of Sanganois CA) during May and June 1995, 24 suitable cavities were flooded in the 97 sample plots and only 46 suitable cavities were available to determine wood duck use. Six of 46 (13.0%) suitable cavities were used for nesting by wood ducks yielding a density of 0.124 nests/ha (0.050 nests/ac) (SE = 0.049, $CI_{95} \pm 0.096$). These wood duck nest densities were minimum estimates.

Five of six (83.3%) wood duck nests were located in silver maple (Table 11), but nesting wood ducks used tree species in proportion to their availability ($\underline{X}^2$ = 3.91, 4 df, $\underline{P}$ = 0.407). Likewise, 83.3 percent of the cavities used by wood ducks were located in normal (enclosed, side-entrance) cavities. Goodness-of-fit tests revealed no differences in wood duck use of the three types of cavities ($\underline{X}^2$ = 2.93, 2 df, $\underline{P}$ = 0.231), and, when comparing

Table 11. Numbers and percents for characteristics of suitable cavities used and not used by wood ducks for nesting at Sanganois Conservation Area during spring 1995. _P_ values represent frequency distribution comparisons using Fisher's exact tests (2 x 2 comparison) or Chi-square goodness-of-fit tests.

	Suitable cavities				
	Used by wood ducks		Not used by wood ducks		
Variable	_n_	Percent	_n_	Percent	_P_
Tree species					
Silver maple	5	83.3	29	72.5	0.407
Red ash	0	0.0	3	7.5	
Willow	0	0.0	4	10.0	
Eastern cottonwood	0	0.0	3	7.5	
American sycamore	1	16.7	1	2.5	
Cavity type					
Normal	5	83.3	27	67.5	0.231
Bucket	0	0.0	11	27.5	0.306[a]
Combination	1	16.7	2	5.0	
Stem type					
Trunk	3	50.0	31	77.5	0.173
Branch	3	50.0	9	22.5	
Tree status					
Alive	3	50.0	23	57.5	1.000
Dead	3	50.0	17	42.5	
Cavity formation					
Natural	2	16.7	32	80.0	0.053
Pileated woodpecker	3	50.0	6	15.0	0.054[b]
Both	1	33.3	2	5.0	

[a] Fisher's exact test _P_ value comparing normal side entrance vs. bucket cavities.
[b] Fisher's exact test _P_ value comparing pileated woodpecker vs. naturally formed cavities.

only normal and bucket cavities, wood duck use was proportional to their availability (Fisher's exact test, $\underline{P} = 0.306$). The type of stem (trunk or branch) containing suitable cavities was used in proportion to its availability (Fisher's exact test, $\underline{P} = 0.173$).

Three of six (50.0%) wood duck nests were located in living trees and this was in proportion to their availability (Fisher's exact test, $\underline{P} = 1.00$) (Table 11). Although 50 percent of the wood duck nests were located in pileated woodpecker cavities, goodness-of-fit tests indicated that wood ducks used cavities of differing formation in proportion to their availability ($\underline{X}^2 = 5.89$, 2 df, $\underline{P} = 0.053$) (Table 11). Even when suitable cavities formed both by natural factors and pileated woodpeckers were excluded, wood duck use of pileated woodpecker cavities was in proportion to their availability (Fisher's exact test, $\underline{P} = 0.054$). In both tests, $\underline{P}$ values were nearly significant denoting the relatively high use of pileated woodpecker cavities by wood ducks.

Goodness-of-fit tests for circular data verified that entrances of suitable cavities were not oriented in any specific direction ($\underline{X}^2 = 7.0$, 7 df, $\underline{P} \geq 0.05$), and that orientation of wood duck nest cavities did not differ from those of unused suitable cavities ($\underline{X}^2 = 5.93$, 7 df, $\underline{P} > 0.05$).

Variables representing suitable cavities and their respective trees differed between suitable cavities used and not used by nesting wood ducks (Table 12). Wood duck nest cavities had smaller horizontal entrance widths (EWIDTH) ($\underline{\bar{x}} = 8.26$ cm, SD = 1.06) (Mann-Whitney $|z| = 2.84$, $\underline{P} = 0.004$) and vertical entrance lengths (ELENGTH)($\underline{\bar{x}} = 12.07$ cm, SD = 3.19) (Mann-Whitney $|z| = 2.97$, $\underline{P} = 0.003$) than unused suitable cavities. Internal cavity height above the cavity entrance (HAE) was significantly greater for wood duck nest cavities ($\underline{\bar{x}} = 97.79$ cm, SD = 30.09) (Mann-Whitney $|z| = 3.41$, $\underline{P} = 0.001$) than for unused suitable cavities ($\underline{\bar{x}} = 28.21$ cm, SD = 41.94). Additionally, when

Table 12. Cavity and cavity tree variables for used and unused suitable wood duck nest cavities at Sanganois Conservation Area during spring 1995. Row means not sharing the same letter were statistically different ($P \leq 0.05$, Mann-Whitney tests).

	Suitable cavities			
	Used by wood ducks		Not used by wood ducks	
Variables	Mean (n)	SD	Mean (n)	SD
Cavity[a]				
EHEIGHT[b]	10.46 (6) A	3.15	8.52 (40) A	3.49
EWIDTH[c]	8.26 (6) A	1.06	15.67 (40) B	8.05
ELENGTH[c]	12.07 (6) A	3.19	34.61 (40) B	28.50
DEPTH[c]	89.75 (6) A	85.73	76.17 (40) A	90.81
HAE[c,d]	97.79 (6) A	30.09	28.21 (38) B	41.94
CWE[c]	22.86 (6) A	7.36	26.35 (40) A	16.79
CLE[c]	23.71 (6) A	4.15	25.40 (40) A	14.58
PLATW[c,e]	19.30 (5) A	3.52	24.80 (38) A	10.53
PLATL[c,e]	19.56 (5) A	3.31	24.80 (38) A	11.77
Tree[a]				
EDBH[c]	16.87 (6) A	2.25	18.93 (40) A	6.37
THEIGHT[b]	25.40 (6) A	1.59	21.35 (40) A	6.01
TDBH[c]	28.12 (6) A	9.64	25.28 (40) A	8.43

[a] EHEIGHT = entrance height; EWIDTH = entrance width; ELENGTH = entrance length; DEPTH = cavity depth below entrance; HAE = height of cavity above entrance; CWE = cavity width at entrance; CLE = cavity length at entrance; PLATW = platform width; PLATL = platform length; EDBH = diameter of the tree bole at entrance; THEIGHT = tree height; TDBH = diameter of bole at breast height.

[b] In meters.

[c] In centimeters.

[d] HAE could not be measured for two unused suitable cavities.

[e] Platform dimensions could not be measured for one wood duck nest cavity and two unused suitable cavities.

only normal (enclosed, side-entrance) cavity types were considered (n = 30), HAE for wood duck nest cavities ($\bar{x}$ = 96.52 cm, SD = 33.46, n = 5) was larger than for unused suitable cavities ($\bar{x}$ = 38.51 cm, SD = 46.80, n = 25) (Mann-Whitney $|z|$ = 2.65, P = 0.008).

Differences were detected in the basal area and tree density near wood duck nest cavities compared with unused suitable cavities (Tables 13 and 14). The forest stand basal area of all trees (PTOTAL) around wood duck nest cavities ($\bar{x}$ = 36.92 m^2/ha, SD = 1.69) was higher than that for unused suitable cavities ($\bar{x}$ = 30.29 m^2/ha, SD = 5.22) (Mann-Whitney $|z|$ = 2.95, P = 0.003) (Table 13). American sycamore in the immediate vicinity of wood duck nest sites had higher densities ($\bar{x}$ = 0.83 trees/0.05 ha, SD = 1.33) than at unused suitable cavity sites ($\bar{x}$ = 0.08 trees/0.05 ha, SD = 0.27) (Mann-Whitney $|z|$ = 2.02, P = 0.043) (Table 14).

The hypothesis that the overall wood duck use of cavities did not differ across the cavity, cavity tree, and cavity site variables was examined for EHEIGHT, EWIDTH, ELENGTH, DEPTH, HAE, CWE, CLE, PLATW, PLATL, EDBH, TDBH, THEIGHT, PTOTAL, TTOTAL, and DTOTAL (Table 1). Forty-one observations were used for analyses and five observations were excluded because of missing values. The MANOVA model detected significant differences between variables measured at wood duck nest cavities and unused suitable cavities (Hotelling-Lawley Trace, F = 2.34, 15, 25 df, P = 0.029). ANOVA indicated EWIDTH (F = 4.69, 40 df, P = 0.037) was significantly smaller, and HAE (F = 13.73, 40 df, P = 0.001) and PTOTAL (F = 6.28, 40 df, P = 0.0165) were significantly higher at wood duck nest cavities than at unused suitable cavities. However, R^2 values for all three variables (EWIDTH, HAE, PTOTAL) were low (0.107-0.260) and explained little of the variation in the wood duck use of suitable cavities.

Table 13. Forest stand basal area (m^2/ha) surrounding trees containing suitable cavities used and not used by nesting wood ducks at Sanganois Conservation Area, 1995. Row means not sharing the same letter were statistically different ($\underline{P} \leq 0.05$, Mann-Whitney tests).

	Basal areas surrounding suitable cavities			
	Used by wood duck (n=6)		Not used by wood ducks (n=40)	
Species	Mean	SD	Mean	SD
Silver maple	22.86 A	11.74	18.79 A	7.72
Eastern cottonwood	3.54 A	5.09	3.69 A	4.92
Pin oak	3.54 A	8.67	0.29 A	0.82
Red ash	2.39 A	2.87	3.73 A	3.94
American sycamore	1.63 A	2.82	0.24 A	0.66
Elm	1.53 A	2.23	1.46 A	1.72
Pecan	0.57 A	1.15	0.30 A	0.90
Willow	0.29 A	0.70	0.79 A	1.88
Unknown	0.29 A	0.70	0.17 A	0.39
Hackberry	0.19 A	0.47	0.06 A	0.28
Box elder	0.10 A	0.23	0.26 A	0.65
River birch	0.00 A	0.00	0.19 A	0.54
White oak	0.00 A	0.00	0.06 A	0.22
Black oak	0.00 A	0.00	0.16 A	1.00
Mulberry	0.00 A	0.00	0.03 A	0.13
Hickory	0.00 A	0.00	0.01 A	0.09
Sassafras	0.00 A	0.00	0.01 A	0.09
Honey locust	0.00 A	0.00	0.04 A	0.20
Total	36.92 A	1.69	30.29 B	5.22

Table 14. Basal area (m^2/ha), density (trees/0.05 ha), and dbh (cm) of trees within 0.05-ha circular plots (immediate vicinity) centered on trees with suitable cavities used and not used by wood ducks at Sanganois Conservation Area, 1995. Row means not sharing the same letter were statistically different ($\underline{P} \leq 0.05$, Mann-Whitney tests).

	Suitable cavities			
	Used by wood ducks (n=6)		Not used by wood ducks (n=40)	
Tree variables by species	Mean	SD	Mean	SD
Basal area (m^2/ha)				
Silver maple	33.24 A	33.28	24.10 A	16.41
Eastern cottonwood	5.77 A	9.04	2.81 A	6.80
Red ash	4.20 A	9.46	3.73 A	5.46
American sycamore	1.66 A	3.11	0.23 A	1.41
Elm	1.65 A	2.72	1.75 A	2.47
Pecan	0.91 A	2.24	0.56 A	2.08
Pin oak	0.39 A	0.94	0.19 A	0.90
Unknown	0.30 A	0.54	0.06 A	0.25
Swamp privet	0.21 A	0.52	0.06 A	0.25
Box elder	0.12 A	0.30	0.34 A	1.20
White oak	0.10 A	0.24	0.29 A	1.20
Willow	0.00 A	0.00	0.88 A	3.28
Black oak	0.00 A	0.00	0.52 A	3.30
Mulberry	0.00 A	0.00	0.10 A	0.42
River birch	0.00 A	0.00	0.11 A	0.59
Hackberry	0.00 A	0.00	0.24 A	1.49
Redbud	0.00 A	0.00	0.01 A	0.06
Total	48.55 A	25.10	35.99 A	14.98
Density (trees/0.05 ha)				
Silver maple	9.50 A	5.21	8.90 A	5.60
Elm	4.00 A	7.13	3.13 A	4.01
Red ash	2.17 A	4.40	2.75 A	4.38
Swamp privet	1.00 A	2.45	0.25 A	1.10
American sycamore	0.83 A	1.33	0.08 B	0.27
Eastern cottonwood	0.67 A	1.03	0.53 A	1.13
Unknown	0.67 A	1.03	0.13 A	0.52
Pecan	0.50 A	1.22	0.18 A	0.59
Pin oak	0.33 A	0.82	0.23 A	1.16
White oak	0.17 A	0.41	0.10 A	0.50
Box elder	0.17 A	0.41	0.08 A	0.27
Willow	0.00 A	0.00	0.50 A	1.80
Black oak	0.00 A	0.00	0.08 A	0.47

Table 14. Continued.

Tree variables by species	Suitable cavities: Used by wood ducks (n=6) Mean	SD	Not used by wood ducks (n=40) Mean	SD
Density (trees/0.05 ha) continued.				
Mulberry	0.00 A	0.00	0.40 A	1.19
River birch	0.00 A	0.00	0.08 A	0.27
Hackberry	0.00 A	0.00	0.25 A	1.58
Redbud	0.00 A	0.00	0.05 A	0.32
Total	20.00 A	9.84	17.58 A	6.98
dbh (cm)				
Total	37.42 A	17.50	32.48 A	9.50

Nest Success

During the nesting seasons of 1994 and 1995, 16 wood duck nests were located in natural cavities at Sanganois CA: 6 nests (37.5%) were destroyed by raccoons, 3 nests (18.8%) hatched successfully, the fates of 2 nests (12.5%) could not be determined, and 5 nests were either abandoned (1), predated by a woodpecker (Family Picidae, Subfamily Picinae) (1), predated by a bull snake (*Pituophis melanoleucus*) (1), predated by a southern flying squirrel (*Glaucomys volans*) (1), or flooded (1). Thus, a simple estimate of the nest success in natural cavities examined was 21.4 percent. Mann-Whitney comparisons between tree and cavity variables measured at successful nests and those nests destroyed by raccoons in 1994 revealed no significant differences ($P > 0.05$).

Effects of the 1993 and 1995 Floods

Tree mortality was examined to determine the effects of extreme flooding on the forest. Seventy-five trees containing suitable cavities were alive in December 1993. By July 1995, 32 of the 75 trees had died, a mortality of 42.7 percent, and many more were stressed from the high water levels of fall 1992, the growing season of 1993, and May-June 1995.

Tree Climbing

An effort was made to determine the amount of time needed to climb trees and inspect cavities using the single rope, rope-walking technique, including the placement and anchoring of the climbing rope. In 1995, 42 cavities were sampled with a mean entrance height of 8.11 m (26.61 ft) (SD = 3.28). These cavities required an average of 24.9 minutes (SD = 11.4) for climbing and inspection. Correlation analysis revealed a significant relationship ($P < 0.001$) between the amount of time needed for climbing and inspection of cavities and EHEIGHT. However, the Pearson product-moment correlation coefficient ($\underline{r}_{xy}$ = 0.613) only explained 38 percent of the variation between the time it took to ascend and inspect cavities and their entrance heights.

DISCUSSION

Cavity Density

The density of cavities suitable for nesting by wood ducks was 2.12 cavities/ha of bottomland forest at Sanganois CA and was relatively high when compared with other areas in North America (Table 15). Only three previous surveys indicated higher densities of suitable cavities for nesting by wood ducks. Haramis (1975) found 3.95 suitable cavities/ha in New York. Gilmer et al. (1978) reported 4.2 suitable cavities/ha in Minnesota. The highest suitable cavity density found in the literature was 5.5 cavities/ha and was reported from virgin stands of silver maple and American elm in New Brunswick (Prince 1968). Whereas these studies had greater densities of suitable cavities, all three sampled much less area (6.58-8.36 ha) than the present study (48.5 ha). Cavity densities reported from Minnesota may have been inflated because Gilmer et al. (1978) did not conduct an actual inspection of individual cavities, but assumed that 21 percent of the potential cavities were suitable as wood duck nest sites as reported by Dreis and Hendrickson (1952).

Suitable cavity densities at Sanganois CA were greater than, but somewhat comparable with, densities found in Kentucky (1.26 cavities/ha; Frederick and Vrtiska 1991), Indiana (1.23 cavities/ha; Robb 1986, Robb and Bookhout 1995), and Missouri (0.70 cavities/ha; Hartowicz 1963). Suitable cavity densities in other geographic regions ranged from 0.07 to 0.67 cavities/ha (Table 15). Suitable cavity densities at Sanganois CA exceeded the suggested wood duck habitat management requirements of 0.5 cavities/ha of forest (McGilvrey 1968, DeGraaf 1991).

Table 15. Comparison of the densities (number of cavities/ha in decreasing order) and the number of natural cavities suitable for and used by nesting wood ducks in other studies[a].

	Suitable cavities				
Location	Number/ha	Number found	Number used (%)	Forest type	Source
New Brunswick	5.50			Bottomland	Prince (1968)
Minnesota[b]	4.20			Upland	Gilmer et al. (1978)
New York	3.95	26	14 (53.8)	Greentree	Haramis (1975)
Illinois	2.12	80	10 (12.5)	Bottomland	This study
		46	6 (13.0)		
Kentucky	1.26	39	9 (23.1)	Combined[c]	Frederick and Vrtiska (1991)
Indiana	1.23	122	37 (30.3)	Combined	Robb (1986)
	1.47			Bottomland	
	0.94			Upland	
Missouri	0.70	8	0 (0.0)	Bottomland	Hartowicz (1963)
Georgia	0.67	22	9 (40.9)	Bottomland	Almand (1965)
Wisconsin	0.65	13	1 (7.7)	Combined	Soulliere (1985, 1988)
	1.07			Upland	
	0.40			Bottomland	
Mississippi	0.66	27	0 (0.0)	Bottomland	Strange (1970)
Minnesota	0.63	54	9 (16.7)	Combined	Nagel (1969)
	1.00	40		Upland	
	0.64	6		Bottomland	
	0.22	8		Aspen	
Mississippi	0.57	30	8 (26.7)	Bottomland	Teels (1975)
Illinois	0.51[d]	105	39 (37.1)	Upland	Bellrose et al. (1964)
	0.15			Bottomland	
Illinois	0.47	130		Upland	Johnson (1959)
Missouri	0.33	17	0 (0.0)	Combined	Weier (1966)
	0.72	12	0 (0.0)	Upland	
	0.14	5	0 (0.0)	Bottomland	
Georgia	0.24	17	6 (35.3)	Upland	Sisson and Engstrom (In press)

Table 15. Continued.

Location	Suitable cavities			Forest type	Source
	Number/ha	Number found	Number used (%)		
Mississippi	0.20	23	0 (0.0)	Bottomland	Lowney (1987)
Iowa	0.10	11	4 (36.4)	Bottomland	Dreis and Hendrickson (1952)
Michigan	0.11	90	4 (4.4)	Bottomland	Boyer (1974)
Louisiana, Mississippi, and Alabama	0.08	2	1 (50.0)	Bottomland	Lee (1991)
Mississippi	0.07	1	0 (0.0)	Bottomland	Woods (1964)
Illinois		211	48 (22.7)	Upland	Shake (1967)
Massachusetts		22	10 (45.5)	Bottomland	Grice and Rogers (1965)

[a] Modified from Bellrose and Holm (1994).
[b] Estimated density using 20 percent of the total number of cavities observed.
[c] Represents bottomland and upland forest.
[d] Averaged for 6 years of data.

Wood duck use of natural cavities was investigated in upland black oak (Quercus velutina) woodlots in central Illinois between 1938-1966 (Johnson 1959, Meyers 1962, Bellrose et al. 1964, Shake 1967); however, much lower densities (0.47-0.51 cavities/ha) were found compared with the present study. In contrast to the studies in upland woodlots, relatively little natural cavity research has been done in Illinois bottomland forests. A preliminary survey in 1944 of 147 ha of bottomland forest near the Sanganois CA revealed 0.15 suitable cavities/ha (Bellrose et al. 1964), which was far less than the 2.12 cavities/ha documented 50 years later in this study. Direct comparisons between the previous surveys and the current study were not possible because of the differences in the type of habitat (upland vs. bottomland) and the omission of recording forest stand characteristics in the earlier surveys. However, the higher density of 2.12 cavities/ha we found in the bottomland compared with the 0.15 cavities/ha previously reported was likely due to the aging (50 yrs) of the forest stand between the studies.

Densities of suitable cavities tend to be higher in northern North America forests than in southern forests (Gilmer et al. 1978, Lowney and Hill 1989), and this trend was evident in the literature (Table 15). Densities of suitable natural cavities in central Illinois fell between those found in the northern and southern states. Cavity-producing tree species common in northern states occur in lower densities in southern states thereby contributing to the latitudinal variation in cavity densities (Bellrose and Holm 1994). Also, tree injuries in the South heal more quickly than in the North, thus decreasing the rate of cavity formation (Lowney 1987).

Willow, American sycamore, and silver maple were the most important cavity-producing trees at Sanganois CA. All three species have been reported to contain wood duck nest cavities, but willow has not been mentioned as frequently as American sycamore and silver maple (Hansen 1966). McGilvrey

(1968) listed American sycamore, silver maple, and black willow (Salix nigra) among the most desirable tree species forming suitable cavities in the Great Lake states of the Midwest, and black willow was a major cavity-producing tree species in Mississippi (Strange et al. 1971). Likewise, Prince (1968) and Haramis (1991) considered silver maple to be an important cavity producer, and American sycamore was a good cavity-producing species in southcentral Indiana (Robb 1986) and Georgia (Frederick and Vrtiska 1991). Lowney (1987) also indicated that American sycamore and willow were important cavity producers and silvicultural practices should favor these species.

Wood duck use of cavity-producing tree species occurred in proportion to their availability in both years of this study. No wood duck nests were located in willow cavities, which indicated that the lack of cavity use was a function of the small number of willow trees in the sample. Willow, American sycamore, and silver maple produced cavities at a relatively young age (53-68 yrs) making them desirable for management of wood ducks and other cavity-nesting species. Red ash was a less desirable species for producing suitable cavities at Sanganois CA than willow, American sycamore, and silver maple; it had a lower importance rating and required a much older age (108 yrs) for production of suitable cavities.

Cavity Use and Selection

Wood duck selection of pileated woodpecker cavities for nesting was detected in 1994, and, although not significant, a relatively high nesting use of pileated woodpecker cavities by wood ducks was found in 1995. Gilmer et al. (1978) suggested that the selection of trees by woodpeckers probably influenced cavity use by wood ducks in Minnesota. Selection of pileated woodpecker cavities at Sanganois CA was likely a result of a preference for the small entrance dimensions of the excavated cavities (Soulliere 1990). The small entrance (10 x 13 cm) (Bull and Meslow 1977) and other dimensions (DEPTH

- 56 cm, EHEIGHT - 13 m, internal diameter - 23 cm) (Bull and Meslow 1977) of pileated woodpecker cavities made them somewhat predator resistant. Pileated woodpeckers have shown a tendency to prefer dead snags for excavation (Southgate and Hoyt 1941, Hoyt 1957, Bull and Meslow 1977, Graber et al. 1977); however, pileated woodpeckers excavated cavities in both living and dead trees at Sanganois CA. Because wood ducks demonstrate a tendency to occupy nest cavities in which they hatched or previously nested successfully (Bellrose et al. 1964, Bellrose and Holm 1994), selection of predator-resistant nest cavities is beneficial.

Haramis (1990) stated that pileated woodpeckers were important to wood ducks because of their excavation of suitable cavities. Previous studies have reported the use of pileated woodpecker cavities by wood ducks (Hoyt 1957, Meyers 1962, Weier 1966, Nagel 1969, Gilmer 1971, Robb 1986, Haramis 1991, Strangel 1994), and 22 avian and 24 mammalian species utilized vacated woodpecker cavities in the Blue Mountains of Oregon (Bull and Meslow 1977). The increased wood duck population in Ontario has been attributed to the population expansion of pileated woodpeckers (Cringan 1971). In Georgia, wood ducks nested in red-cockaded woodpecker (Picoides borealis) cavities (Loeb 1993; Sisson and Engstrom, In Press). Similarly, buffleheads (Bucephala albeola) have been found to utilize cavities excavated by northern flickers (Colaptes auratus) in British Columbia (Erskine 1960, 1971). McCabe (1993) suggested that pileated woodpecker cavities were readily available to wood ducks, and that nesting wood ducks would not be as abundant without pileated woodpeckers. Wood ducks and pileated woodpeckers have apparently coevolved as indicated by the preference of pileated woodpecker cavities for nesting by wood ducks, their use of similar habitats (Hoyt 1957, Bellrose and Holm 1994), and their overlapping range distributions (Graber et al. 1977, Bellrose and Holm 1994).

Cavity use by female wood ducks varied according to the characteristics of cavities and stands. In both the 1994 and 1995 nesting seasons, wood ducks preferred cavities with smaller EWIDTHs and ELENGTHs. Weier (1966) suggested that wood ducks nest in cavities with small entrance dimensions to evade raccoon predation. Adult raccoons north of the Mason-Dixon Line were unable to invade cavity entrances smaller than 7.6 x 10.2 cm (Webster and Uhler 1964).

Similar research revealed a preference by wood ducks and other cavity-nesting species for small cavity entrance dimensions (Soulliere 1990, Newton 1994). In Illinois, Indiana, and Kentucky, wood ducks selected suitable cavities with small entrance dimensions (Meyers 1962, Bellrose et al. 1964, Robb 1986, Frederick and Vrtiska 1991, Robb and Bookhout 1995). Use of cavities by wood ducks increased as entrance dimensions decreased in Louisiana and Mississippi (McComb and Noble 1981). Likewise, artificial nest boxes with smaller entrances were used more by wood ducks than those with larger entrances in Ontario (Richardson and Knapton 1993). A study using simulated bird nests revealed decreased rates of predation in natural cavities with small entrance dimensions (Sandstrom 1991). Peterson and Gauthier (1985) examined natural cavity use by six avian species in British Columbia, and all utilized cavities with smaller entrance dimensions.

In 1994 and 1995, wood duck nests were located in forest stands with larger basal areas (PTOTAL) than unused suitable cavity sites, which indicated wood ducks preferred older, more mature sections of the forest. In contrast, wood ducks selected open forest for nest sites in New Brunswick (Prince 1968), and artificial nest boxes placed in open stands of mature trees in Illinois had higher use rates by wood ducks (Bellrose et al. 1964). Gilmer et al. (1978) indicated that basal area of the forest was not important for wood duck nest site selection in Minnesota. In southcentral Indiana, however, wood ducks selected nest sites in forest stands with larger basal areas (Robb and Bookhout 1995), which was similar to our findings from Sanganois CA. Robb and Bookhout (1995) suggested forest basal area may be a secondary factor in wood duck nest site selection because wood ducks would have limited opportunities to select for large basal area in second-growth timber. Wood ducks may have selected forest stands at Sanganois CA with many large trees to reduce the risk of predation; predators would have to search more to locate nests than in open stands. Pileated woodpeckers have also been reported to use forest stands with large basal areas (Conner and Adkisson 1977).

Other differences detected between wood duck nest sites and unused suitable cavity sites occurred in the 1994 nesting season. EDBH and PLATW were smaller for wood duck nest sites than unused suitable cavities indicating a preference by wood ducks for smaller cavity volume. Preference for smaller cavity volumes by wood ducks has been reported as an antipredator strategy in Illinois and Indiana (Bellrose et al. 1964, Robb 1986). Likewise, less predation was encountered in simulated avian nests in natural cavities with smaller volumes (Sandstrom 1991).

EHEIGHT was also higher for wood duck nest sites than unused suitable cavity sites during 1994. Heights of wood duck nests have been reported as low as 0.6 m and as high as 22.9 m (Bellrose 1980) with more use occurring in higher cavities (Johnson 1959, Meyers 1962, Bellrose et al. 1964, Bookhout 1986, Soulliere 1990). Increased use of natural cavities by Carolina chickadees (Parus carolinensis) has also been reported in higher nest sites (Albano 1992), and many studies have observed decreased nest predation with increasing elevation of natural cavities (Best and Stauffer 1980, Nilsson 1984, Rendell and Robertson 1989, Albano 1992). However, EHEIGHT did not affect cavity use by buffleheads in British Columbia (Erskine 1960, 1971).

TTOTAL in the immediate vicinity of wood duck nest sites and the forest stand basal area of silver maple at wood duck nest sites were larger than at unused suitable cavity sites during 1994. In contrast, Robb (1986) reported that immediate vicinity basal area and tree density were not associated with wood duck nest site selection in southcentral Indiana. The HAE and basal area of American sycamore in the immediate vicinity of wood duck nest sites were greater than at unused suitable cavities during 1995. Although these factors were significant in a given year, their overall influence on wood duck nest cavity selection at Sanganois CA may not be as important.

Nest Success

Wood duck nest success at Sanganois CA varied from 33.3 percent in 1994 to no nests hatched in 1995 for an overall nest success rate of 21.4 percent during the 2 years of the study (Table 16). Monitoring of natural cavities during the springs of 1994 and 1995 occurred under water level extremes. In 1994, river water levels receded from the forest before the wood duck nesting season and dry conditions remained until fall. In 1995, record floods were observed 8 km downstream of Sanganois CA during the peak of the nesting season and wood duck nest success on our study area fell to zero. These results indicated that during normal years (1994) nest success in floodplain forests may be as high as 33 percent, but during extreme flood years (1995), wood duck production may be negligible. Similar evidence suggesting decreased production by wood ducks during flood years was observed in southern Illinois (Robert J. Gates, 1995, Southern Illinois University at Carbondale, pers. commun.). Other evidence suggested that nest predation was reduced with an increase in suitable cavities (Robb and Bookhout 1995). The reverse of this relationship occurred at Sanganois CA during 1995 when 34 percent ($\underline{n}$ = 24) of the suitable cavities were flooded, thereby decreasing cavity density and increasing the nest predation rate to 80 percent.

Table 16. Wood duck nest success rates (in decreasing magnitude) in natural cavities from various regions of North America.

Location	Number of nests	Nest success (%)	Forest type	Source
Mississippi	16	75.0	Bottomland	Teels (1975)
California	12	66.7	Upland	Dixon (1924)
Georgia	9	44.4	Bottomland	Almand (1965)
Illinois	69	52.2	Upland	Johnson (1959)
Mississippi	2	50.0	Bottomland	Lowney (1987)
New Brunswick	24	50.0	Bottomland	Prince (1968)
Illinois	158	39.9	Upland	Bellrose et al. (1964), Meyer (1962)
Illinois	19	33.3[a]	Bottomland	This study
	5	0.0[b]		
	14	21.4[c]		
Missouri	6	33.3	Combined[d]	Weier (1966)
Illinois	48	31.3	Upland	Shake (1967)
Louisiana, Mississippi, and Alabama	4	25.0	Bottomland	Lee (1991)
Indiana	22	22.0[e]	Combined	Robb (1986)
	11	36.4		

[a] Nest success in 1994.
[b] Nest success in 1995.
[c] Nest success for 1994 and 1995.
[d] Represents bottomland and upland forest.
[e] Estimated nest success using the Mayfield (1961, 1975) method.

Success rates for wood duck nests similar to those found in this study (21.4%) were reported previously in central Illinois by Bellrose et al. (1964) (39.9%) and Shake (1967) (31.3%); however, Johnson (1959) indicated higher nest success (52.2%) in upland woodlots in central Illinois (Table 16). Other high nest success rates (50-75%) were observed in Mississippi (Teels 1975), California (Dixon 1924), and New Brunswick (Prince 1968). Lowney (1987) reported a wood duck nest success rate in Mississippi of 50.0 percent; however, his sample size was small with only two confirmed nests.

Studies in other geographic locations reported nest success rates of wood ducks similar to those found at Sanganois CA (Table 16). A nest success rate of 44.4 percent was noted in Georgia (Almand 1965), and nest success at Mingo Swamp National Wildlife Refuge in Missouri was estimated at 33.3 percent (Weier 1966). Lee (1991) found one successful nest in four attempts (25%) at selected areas in Louisiana, Mississippi, and Alabama. Robb and Bookhout (1995) reported a 36.4 percent nest success rate in southcentral Indiana for 11 nests located in natural cavities. However, Robb and Bookhout (1995) found lower success (22%) using the daily survival rate (Mayfield 1961, 1975) for nests of radio-collared hens. Albano (1992) also found a reduction in nest success using the Mayfield (1961, 1975) method for Carolina chickadees. Therefore, the simple percentage used to calculate nest success in many studies (including this study) may have inflated wood duck nest success rates. However, wood duck nest success at Sanganois CA during a non-flood year was consistent with other studies in differing locations and habitats.

Raccoons were the primary predator of wood duck nests in natural cavities at Sanganois CA destroying six of 14 nests (42.9%) whose fates were confirmed. Raccoons have been identified as the major predator of nests throughout the range of the wood duck (Haramis 1991), and raccoons accounted for a high percentage of the failure of wood duck nests in Illinois (Meyers

1962, Bellrose et al. 1964, and Shake 1967). Raccoons were responsible for 15 of 22 (68%) predated wood duck nests in southcentral Indiana (Robb 1986). Low nest success and hen survival, attributed to raccoon predation, limited wood duck production in southcentral Indiana (Robb 1986, Robb and Bookhout 1995). Raccoons have also been identified as the principal lethal threat to incubating wood duck hens (Bellrose and Holm 1994). Raccoon harvest (hunting and trapping) should be encouraged at Sanganois CA to reduce predation on nesting wood ducks and their clutches.

Cavity Loss

The annual survival probability (0.88) of suitable cavities at Sanganois CA was similar to that (0.91) observed in southcentral Indiana (Robb and Bookhout 1995). No attempt was made to determine the rate of cavity creation; however, suitable cavity densities at Sanganois CA will likely improve in the short-term due to increased tree mortality caused by flooding and subsequent pileated woodpecker activity (Yeager 1949). However, long-term densities will decrease as decaying trees fall and eliminate suitable cavities (Sedgwick and Knopf 1992). The amount of time required for long-term suitable cavity densities to approximate current densities will be several years or even decades; extant trees and seedlings must mature before forming cavities and becoming available to primary cavity-nesting birds Sedgwick and Knopf 1992).

Tree Mortality

The 42.7 percent mortality of mature trees with suitable cavities at Sanganois CA was a result of protracted flooding from September 1992 through spring 1994 and the record spring flood in 1995. Overall tree mortality rates on Pool 26 and in the open river section of the Upper Mississippi River in 1994 following the Great Flood of 1993 were 37.2 and 32.2 percent, respectively (Yin et al. 1994). Tree mortality rates were higher at Sanganois CA than in the lower parts of the Upper Mississippi River because of the longer period of flooding. Tree mortality at Sanganois CA will likely increase as weakened trees continue to succumb to environmental stresses.

The extreme tree mortality observed at Sanganois CA and elsewhere on the Illinois and Mississippi rivers (Yin et al. 1994) was unexpected because tree species common in the floodplain are adapted to inundation. Green (1947) reported that permanently-flooded trees suffered some mortality after 2 years, but complete mortality required 4 years of permanent inundation. Likewise, on the Illinois River near Grafton, Yeager (1949) indicated that it took 8 years of permanent flooding to kill some of the flood tolerant species, such as white ash (<u>Fraxinus americana</u>), common buttonbush (<u>Cephalanthus occidentalis</u>), swamp privet, and black willow. Havera et al. (1980) combined floodplain tree species into three water level tolerance classes based on work done by Hall et al. (1946), Green (1947), Yeager (1949), Lindsey et al. (1961), and Bell and Johnson (1974). The major tree species at Sanganois CA, based on basal area and tree density (Tables 4, 9, 10, 13, 14), were silver maple, red ash, American elm, eastern cottonwood, American sycamore, and willow. All of these species, except for willow, were grouped by Havera et al. (1980) as moderately tolerant of water levels (withstanding 2-4 years of permanent flooding). Willow was classified as water-tolerant, surviving at least 3 years of permanent inundation (Havera et al. 1980). Data from our study and Yin et al. (1994) demonstrated that protracted extreme flooding during one or more growing seasons can severely affect tree species survival and subsequent forest composition and density in a river floodplain ecosystem.

Tree Climbing

Climbing time varied with EHEIGHT; however, other factors not measured affected climbing time including the density of foliage, increased height of trunk-branch forks, and small fork angles. These three factors decreased the probability of shooting arrows successfully in the desired locations;

additionally, excessive foliage and branches deflected arrows and prevented them from falling to the forest floor. Climbing difficulty and, therefore, climbing time also increased with the number of branches traversed in the ascent to and descent from cavities.

The modified version of the single rope, rope-walking system used during this study differed from the top-rope and lead-climbing technique used by Lowney et al. (1988). The top-rope climbing technique utilizes a lead line to belay a climber, who ascends trees using climbing spikes, a waist harness, and a lanyard. In the rope-walking system, the rope is ascended rather than the tree, and this method was efficient with a mean climbing time of approximately 25 minutes (range 8.8 - 56.8 min, $\underline{n}$ = 42). The top-rope technique averaged approximately 1 hour at each tree with some trees taking several hours to climb (Lowney et al. 1988).

In over 400 cavity inspections ranging in heights of 2.7 to 15.4 m, no falls occurred utilizing the rope-walking system. As long as sound trees and branches (capable of supporting the climber's weight) were used and adequate care was given to climbing equipment, the risk of falling and subsequent injury was minimal. The climber and belayer were at a greater risk of injury from falling debris (dead branches or equipment).

Lowney et al. (1988) estimated expenses for top-rope and lead-climbing equipment at $300 in 1985. In 1993, climbing equipment for the rope-walking system was purchased for two individuals for approximately $1,675 including: two climbing ropes (46 m and 76 m, 2 chest harnesses (equipped with Simmons rollers), 2 waist harnesses, 2 helmets, 4 Jumar ascenders, 2 CMI small ascenders, 4 foot stirrups, 2 six-bar rappelling racks, 2 pair of rappelling gloves, and a various assortment of pulleys, tubular webbing, and self-locking, locking, and nonlocking carabiners. Although equipment for the rope-walking technique was more expensive than for the top-rope-climbing technique used by Lowney et al. (1988), the climbing efficiency and safety of the rope-walking system offset any added costs. The single rope, rope-walking system used in this study would be applicable to research or management operations requiring individuals to access tree canopies.

CONCLUSIONS

The density of natural cavities suitable for nesting by wood ducks at Sanganois CA (2.12 cavities/ha) was greater than, but comparable with, densities reported in surrounding states; however, the cavity density was much higher than previously reported for upland and bottomland forests in central Illinois. Increased age of the bottomland forests was likely the primary reason for the higher cavity densities in central Illinois. Suitable cavity densities at Sanganois CA exceeded the wood duck habitat management recommendations of 0.5 cavities/ha (McGilvrey 1968, DeGraaf 1991).

The most important cavity-producing species were willow, American sycamore, and silver maple. Silver maple produced the highest density of suitable cavities and occupied the greatest basal area. Willow produced the most suitable cavities per unit basal area.

Factors associated with nest predation influenced nest site selection by wood ducks. They preferred pileated woodpecker cavities as well as nest cavities with smaller entrance dimensions that minimize raccoon predation. Wood ducks also used cavities with higher EHEIGHT and with smaller EDBH and PLATW, indicating a preference for cavities with smaller volumes. They nested in suitable cavities in forest stands with the largest basal areas.

Wood duck nest success was comparable with rates in surrounding states, and, as found in other areas, raccoon predation was the principal cause of wood duck nest failures. In springs with a normal flood cycle, wood duck nest success in central Illinois floodplains may be as high as 33 percent; however, in springs with exceptionally high water, wood duck production may be negligible. Raccoon harvest (hunting and trapping) should be encouraged at Sanganois CA and other public areas in the floodplain of major rivers to reduce predation on female wood ducks and their nests.

Severe tree mortality was observed at Sanganois CA as a result of excessive inundation from flood waters of the Illinois and Sangamon rivers. Protracted flooding during three out of four growing seasons dramatically affected tree species composition and density in the floodplain ecosystem. Accordingly, the density of suitable cavities will probably improve in the short-term from the tree mortality and subsequent pileated woodpecker activity. However, cavity densities will eventually decrease as decaying trees fall and suitable cavities become unavailable.

The single rope, rope-walking system was a safe and efficient technique for inspecting natural tree cavities. Whereas the amount of time needed to climb and inspect a suitable cavity was correlated with EHEIGHT, the relationship was not linear, and other factors associated with the cavity tree affected climbing time. The single rope, rope-walking system would be useful for research and management operations requiring individuals to access tree canopies.

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Copies To: John [illegible]
Jeff [illegible]
Cindy Dillman
Steve Havera
Project File
Original To: Equip File

OO

PROPOSED EQUIPMENT BUDGET

PROJECT NAME: Wood Duck Investigations

PROJECT NUMBER: W-118-R

SUBGRANTEE NAME: Illinois Natural History Survey

SEGMENT # 3 ITEM	ESTIMATED COST
None	

TOTAL $

PLEASE LIST ALL ITEMS WITH THE VALUE OF $100 AND MORE.

COMPLETED BY: Stephen P. Havera DATE: 1 April 1994

REVIEWED BY (DOC MANAGEMENT DIVISION): [signature] DATE: 4/20/94

ITEMS TO BE TRANSFERRED TO DOC AT END OF PROJECT SHOULD BE MARKED BY DOC STAFF.

FORM EQ/BUDG 05/11/92

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SUBMITTED BY:

Stephen P. Havera

Stephen P. Havera
Professional Scientist
Illinois Natural History Survey

DATE: 15 September 1995